Advances in Intelligent Systems and Computing AISC 502

Jiuping Xu
Asaf Hajiyev
Stefan Nickel
Mitsuo Gen *Editors*

Proceedings of the Tenth International Conference on Management Science and Engineering Management

Springer

Advances in Intelligent Systems and Computing

Volume 502

Series editor

Janusz Kacprzyk, Polish Academy of Sciences, Warsaw, Poland
e-mail: kacprzyk@ibspan.waw.pl

About this Series

The series "Advances in Intelligent Systems and Computing" contains publications on theory, applications, and design methods of Intelligent Systems and Intelligent Computing. Virtually all disciplines such as engineering, natural sciences, computer and information science, ICT, economics, business, e-commerce, environment, healthcare, life science are covered. The list of topics spans all the areas of modern intelligent systems and computing.

The publications within "Advances in Intelligent Systems and Computing" are primarily textbooks and proceedings of important conferences, symposia and congresses. They cover significant recent developments in the field, both of a foundational and applicable character. An important characteristic feature of the series is the short publication time and world-wide distribution. This permits a rapid and broad dissemination of research results.

More information about this series at http://www.springer.com/series/11156

Jiuping Xu · Asaf Hajiyev
Stefan Nickel · Mitsuo Gen
Editors

Proceedings of the Tenth International Conference on Management Science and Engineering Management

Springer

Editors
Jiuping Xu
Business School
Sichuan University
Chengdu, Sichuan
China

Asaf Hajiyev
Azerbaijan National Academy of Sciences
Baku
Azerbaijan

Stefan Nickel
Karlsruhe Institute of Technology
Karlsruhe, Baden-Württemberg
Germany

Mitsuo Gen
Tokyo University of Science
Fuzzy Logic Systems Institute
Tokyo
Japan

ISSN 2194-5357 ISSN 2194-5365 (electronic)
Advances in Intelligent Systems and Computing
ISBN 978-981-10-1836-7 ISBN 978-981-10-1837-4 (eBook)
DOI 10.1007/978-981-10-1837-4

Library of Congress Control Number: 2016946613

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer Science+Business Media Singapore Pte Ltd.

The original version of the book frontmatter was revised: Author's name and affiliation have been included in the section titles 'Advancement of Intelligent Systems, Computing Methodology, Information Technology and Decision Making Systems Based on the Tenth ICMSEM Proceedings' and 'Advances in Industrial Engineering, Logistics Engineering, Project Management and Risk Management Based on the Tenth ICMSEM Proceedings'. The erratum to the book frontmatter is available at 10.1007/978-981-10-1837-4_139

Preface

Welcome to the Proceedings of the Tenth International Conference on Management Science and Engineering Management (ICMSEM 2016) held from August 31 to September 2, 2016 at Baku, Azerbaijan.

The International Conference on Management Science and Engineering Management (ICMSEM) is an annual conference organized by the International Society of Management Science and Engineering Management (ISMSEM). The goals of the conference are to foster international research collaborations in management science and engineering management (MSEM) as well as to provide a relaxing and enjoyable atmosphere for the presentation of current research through technical sessions and round table discussions.

The ICMSEM has been successfully held 9 years since 2007. The first three ICMSEMs were held in Chengdu, China from July 14 to 21, 2007, Chongqing, China from November 3 to 8, 2008 and Bangkok, Thailand from November 2 to 4, 2009, respectively. The Fourth ICMSEM was held from November 15 to 17, 2010 in Chungli, Taiwan, for which 1326 papers from 33 countries were received and 125 papers accepted. The Fifth ICMSEM was held from November 7 to 9, 2011 in Macau, China, for which 1106 papers from 33 countries were received and 113 papers accepted. In 2012, the Sixth ICMSEM was held at Quaid-i-Azam University, Islamabad, Pakistan from November 11 to 14, for which 1090 papers from 33 countries were received and 90 papers accepted for presentation or poster display. The Seventh ICMSEM was held from November 7 to 9, 2013 at Drexel University, Philadelphia, Pennsylvania, USA, for which 1420 papers from 35 countries were received and 130 papers from 12 countries accepted for presentation or poster display. The Eighth ICMSEM was held in Europe at the Universidade Nova de Lisboa, Lisbon, Portugal from July 25 to 27, 2014, for which 1,337 papers from 37 countries were received and 138 papers from 14 countries accepted. The Ninth ICMSEM was held from July 21 to 23, 2015 at the Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany, for which 971 papers from 35 countries were received and 132 papers from 15 countries accepted. All accepted papers were put into the proceedings for each International Conference on

Management Science and Engineering Management and proceedings for the last four conferences can be retrieved from EI and ISTP.

This year, 985 papers from 37 countries were received and 138 papers from 21 countries accepted for presentation or poster display at the conference. These papers are from Azerbaijan, the USA, the UK, Turkey, Japan, Vietnam, Australia, Pakistan, Spain, Portugal, Iran, the Russia Federation, Uzbekistan, Korea, France, Canada, the Republic of Moldova, Bangladesh, Mongolia, South Africa and China. Papers have been classified into eight parts in the proceedings: Intelligent Systems, Computing Methodology, Information Technology, Decision Making Systems, Industrial Engineering, Logistics Engineering, Project Management and Risk Management. The key issues at the Tenth ICMSEM cover many areas in management science and engineering management, including decision making methods, operations research, computational mathematics, information systems, logistics and supply chain management, computer and networks, ecological engineering, scheduling and control, data warehousing and data mining, electronic commerce, neural networks, stochastic models and simulation, heuristics algorithms, tourism informatics and risk control. To further encourage state-of-the-art research in the field of management science and engineering management, the ISMSEM Advancement Prize for Management Science and Engineering Management is to be awarded for excellent papers at the conference.

We would like to take this opportunity to thank all the participants who have worked so hard to make this conference a success. We want to express our sincere gratitude to the following prestigious academies for their high-quality papers and support for the keynote addresses: the Russian Academy of Sciences, the Mongolian National Academy of Sciences, the Azerbaijan Academy of Sciences, the Moldova Academy of Sciences, the International Academy for Systems and Cybernetic Sciences and the Lotfi Zadeh International Academy of Sciences. We would also like to acknowledge the assistance we received from the International Society of Management Science and Engineering Management and Sichuan University for the conference organization. We also appreciate Springer-Verlag London for the publication of the proceedings. We are also grateful to Professor **Adalat Muradov** for being the General Chair and Prof. Asaf Hajiyev for being the Organizing Committee Chair. We appreciate the great support received from all members of the Organizing Committee, Local Arrangement Committee and Program Committee as well as all participants who have worked so hard to make this conference a success. Finally we would like to thank all researchers for their excellent conference papers. Because of the high quality of the research, the ISMSEM Advancement Prize for MSEM is to be awarded again for papers which have focused on innovative practical applications for management science and engineering management.

The MSEM research is in continuous development, hence many new MSEM development trends have emerged. Our work needs to continue to focus on MSEM development so as to encourage greater and more innovative development activity. Next year, we plan to continue our novel and successful ICMSEM, and intend to increase our efforts to improve the quality of the proceedings and to recommend more excellent papers for the ISMSEM Advancement Prize. The Eleventh International Conference on Management will be hosted by Kanazawa University, Kanazawa, Japan in July 2017. Professor Dr. Mitsuo Gen has been nominated as the Organizing Committee Chair for the 2017 ICMSEM, so we sincerely hope you can submit your new MSEM findings and share your ideas in Kanazawa, Japan.

Chengdu, China Jiuping Xu
Baku, Azerbaijan Asaf Hajiyev
Karlsruhe, Germany Stefan Nickel
Tokyo, Japan Mitsuo Gen
May 2016

Organization

ICMSEM 2016 was organized by the International Society of Management Science and Engineering Management, Sichuan University (Chengdu, China), Ministry of Education of Azerbaijan. It was held in cooperation with Advances in Intelligent Systems and Computing (AISC) of Springer.

Executive Committee

General Chairs:
Prof. Jiuping Xu, Sichuan University, China Academician, Prof. Adalat Muradov, Rector of Azerbaijan State University of Economics.

Program Committee Chairs:
Prof. Hajiyev Asaf, National Academy of Sciences of Azerbaijan, Azerbaijan
Prof. Shavkat Ayupov, Academy of Sciences of Uzbekistan, Uzbekistan
Prof. Le Dung Trang, Abdus Salam ICTP, Vietnamese
Prof. Benjamin Lev, Drexel University, Philadelphia, USA
Prof. José Antonio de la Peñ Mena, Mexican Academy of Sciences, Mexico
Prof. Alberto Pignotti, University of Buenos Aires, Argentina
Prof. Baldev Raj, Indian National Academy of Engineering, India
Prof. Roshdi Rashed, National Center of Scientific Research, France

Organizing Committee Chair:
Academician, Prof. Asaf Hajiyev, Azerbaijan Republic, and Baku State University, Azerbaijan

Local Arrangement Committee Chair:
Prof. Mustafa Babanli, Azerbaijan State Oil and Industry University, Azerbaijan

Local Arrangement Committee:
Dr. Rafig Jamalov, Azerbaijan State Oil and Industry University, Azerbaijan
Dr. Anar Kazimov, Azerbaijan State University of Economics, Azerbaijan
Dr. Natig Ahmadov, Azerbaijan Technical University, Azerbaijan

Program Committee:
Prof. Mohammad Z. Abu-Sbeih, King Fahd University of Petroleum and Minerals, Saudi Arabia
Prof. Joseph G. Aguayo, University of Concepcion, Chile
Prof. Basem S. Attili, United Arab Emirates University, United Arab Emirates
Prof. Alain Billionnet, Ecole National Superieure
Informatics for Industry and Enterprise, France
Prof. Borut Buchmeister, University of Maribor, Slovenia
Prof. Daria Bugajewska, Adam Mickiewicz University, Poland
Prof. Saibal Chattopadhyay, Indian Institute of Management, India
Prof. Edwin Cheng, Hong Kong Polytechnic University, Hong Kong
Prof. Anthony Shun Fung Chiu, De La Salle University, Philippines
Prof. Jeong-Whan Choi, Department of Mathematics, Republic of Korea
Prof. Kaharudin Dimyati, University of Malaya, Malaysia
Prof. Behloul Djilali, University of Sciences and Technology Houari Boumediene, Algeria
Prof. Eid Hassan Doha, Cairo University, Giza, Egypt
Prof. O'Regan Donal, National University of Ireland, Ireland
Dr. Siham El-Kafafi, Manukau Institute of Technology, New Zealand
Prof. Christodoulos A. Floudas, Princeton University, USA
Prof. Masao Fukushima, Kyoto University, Japan
Prof. Oleg Granichin, Sankt-Petersburg State University, Russia
Prof. Bernard Han, Western Michigan University, USA
Dr. Rene Henrion, Humboldt University, Germany
Prof. Voratas Kachitvichyanukul, Asian Institute of Technology, Thailand
Prof. Arne Løkketangen, Molde University College, Norway
Dr. Andres Medaglia, University of the Andes, Colombia
Prof. Venkat Murali, Rhodes University, South Africa
Prof. Shmuel S. Oren, University of California Berkeley, USA
Prof. Turgut Öziş, Ege University, Turkey
Prof. Panos M. Pardalos, University of Florida, USA
Prof. Gianni Di Pillo, Sapienza University of Rome, Italy
Prof. Nasrudin Abd Rahim, University of Malaya, Malaysia
Prof. Celso Ribeiro, Fluminense Federal University, Brazil
Prof. Hsin Rau, Chung Yuan Christian University, Taiwan
Prof. Jan Joachim Ruckmann, University of Birmingham, UK
Prof. Martin Skitmore, Queensland University of Technology, Australia
Prof. Frits C. R. Spieksma, Katholieke University Leuven, Belgium

Prof. Yong Tan, University of Washington, USA
Prof. Albert P. M. Wagelmans, Erasmus University Rotterdam, Netherlands
Prof. Desheng Dash Wu, University of Toronto, Canada
Prof. Hong Yan, Hong Kong Polytechnic University, Hong Kong

Secretary-General:
Prof. Zhineng Hu, Sichuan University, China

Under-Secretary General:
Dr. Lin Zhong, Sichuan University, China
Dr. Zongmin Li, Sichuan University, China
Dr. Rui Qiu, Sichuan University, China

Secretaries:
Ning Ma, Jingqi Dai, Lurong Fan

Contents

Advancement of Intelligent Systems, Computing Methodology, Information Technology and Decision Making Systems Based on the Tenth ICMSEM Proceedings

Jiuping Xu

Abstract Innovation in management science and engineering management have significantly influenced international economic advancement through the development of efficient innovative managerial tools, developments that will continue to exponentially increase. In this paper, we first give an introduction to the tenth ICMSEM Proceedings Volume I, the goal of which is to present new research on intelligent Systems, computing methodology, information technology and decision making systems. Then, a literature review focuses on the main research content from these four areas, after which we summarize the central issues in the Tenth ICMSEM Proceedings Volume 1 in terms of research foci and conclusions. Finally, we examine the works presented at the ICMSEM by focusing on the MSEM advancements that have been made in the last year. ICMSEM continues to provide a valuable forum academic exchange and communication and will continue to play an important role in promoting MSEM advancements in the future.

Keywords Intelligent systems · Computing methodology · Information technology · Decision making systems

Introduction

We are very pleased that the Tenth International Conference on Management Science and Engineering Management (ICMSEM) held in Baku, Azerbaijan, has given the opportunity to once again give management science and engineering management (MSEM) academics the opportunity to present their innovative findings in this increasingly popular research fied. The papers in this volume demonstrate the substantial and important growth in the methodological development and practical

J. Xu (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: xujiuping@scu.edu.cn

application for MSEM interdisciplinary problems. The ICMSEM aims to be the primary forum, where both academic researchers and practitioners can become involved in discussions on state-of-the-art MSEM research and development.

MSEM has displayed tremendous growth and expansion since its very beginning. Management science (MS) had a long history associated with universal and impersonal management research disciplines. Scientific management, of course, owes its beginnings to the innovative ideas of Frederick Taylor and Henri Fayol, and their associates, who, at the turn of the twentieth century attempted to solve industry problems through strict time monitoring, technical production methods, incentive wage payments, and rational factory organization based on efficiently structured work assignments [1, 5]. In the period following the Second World War, modern analytical management methods brought business practice into a new era. Terms such as Decision Theory, Operations Research, Systems Engineering, and Industrial Dynamics, which were practically unknown in the early 1950s are now as well known as Accounting or Finance [12]. As time passed, with societal, economic, organizational and cultural factors playing increasingly more important roles in management practice, MS used mathematics information science, systems science, cybernetics, statistics and other theories and methods from natural science to develop innovative management and control system. The integration of these research areas has brought significant improvements to MS. Volume I of ICMSEM proceedings focuses mainly on Intelligent Systems, Computing Methodology, Information Technology and Decision Making Systems.

Literature Review

Literature reviews are useful in gaining insight into particular research fields and can assist in revealing new research directions. In this section, we present a literature review on Intelligent Systems, Computing Methodology, Information Technology and Decision Making System in the study for MSEM.

Intelligent Systems

First of all, with genetic algorithms and simulation as the key concepts, intelligent systems (IS) are basis for all MSEM tools, as they provide the foundation for the discussion of practical management problems. Wang and Fei [25] presented an overview of the background, concepts, basic methods, major issues, and current applications of Parallel transportation Management Systems (PtMS). Zilberstein [26] surveyed the main control problems related to optimal management of uncertainty and precision that arise when a system is composed of several anytime algorithms. Work with newer types of intelligent systems and help functions for everyday systems, such as word processors, often appeared to neglect the lessons learned from the past. However, Gregor and Benbasat [10] attempted to rectify this situation by drawing together a considerable body of work on the nature and use of explanations. Lin and Cheng's [19] alternative method for using neural network algorithms has achieved satisfactory results for fast and precise harmonic detection in noisy environments by providing only 1/2 cycle sampled values for distorted waveforms to the neural network. Many scholars have studied intelligent systems and have had achievements that have been applied across many different fields.

Computing Methodology

Computing methodology (CM) is the theoretical foundation for dealing with management science and engineering management problems. In past studies, Luo and Shao [20] presented a hybrid soft computing modeling approach based on rough set theory and genetic algorithms (GA), the neurofuzzy system. To solve the curse of the dimensionality problem in neurofuzzy systems, rough sets were used to obtain a reductive fuzzy rule set. Gross [11] characterized cooperative ambient intelligence, revisited existing methods, and discussed what constituted a novel human-centered computing methodology. Lee and Chiang [17] developed a novel dynamical trajectory based methodology for systematically computing multiple local optimal solutions for general nonlinear programming problems with disconnected feasible components to satisfy nonlinear equality/inequality constraints. The proposed methodology, which was deterministic in nature, exploited the trajectories of two different nonlinear dynamical systems to derive multiple local optimal solutions. Cooper and Giuffrida [7] developed and illustrated a new knowledge discovery algorithm tailored to the action requirements of management science applications. This combination meant that a more complete array from the information cart could be used to develop tactical planning forecasts.

Information Technology

Information technology (IT) is an appropriate technical platform for the solving of practical management problems, and has been defined by the Information Technology Association of America as the study, design, development, implementation, support or management of computer-based information systems, particularly software applications and computer hardware. IT is playing an increasingly dominant role in modern society and, as a result, Information technology (IT) acceptance research has yielded many competing models, each with different sets of acceptance determinants. Venkatesh et al. [24] reviewed user acceptance literature, discussed and empirically compared eight prominent models and their extensions, formulated a unified model that integrated elements across the eight models, and empirically validated the unified model. Ash et al. [3] believed that with a heightened awareness of these issues, informaticians could educate, design systems, implement, and conduct research in such a way that they might be able to avoid the unintended consequences of these subtle silent errors. Lewis et al. [18] developed a research note by building upon and extending prior research that examined the factors that influenced the key individual beliefs about technology use. It has been argued that people form their beliefs about their use of information technologies from within the broad range of individual, institutional, and social influences that interact with IT. Bhatt and Grover [6] contrasted traditional thinking about competitive advantage with a resource-based view and specifically argued that by demarcating specific types of capabilities, a better understanding of the sources of IT-based competitive advantage could be gained.

Decision Making System

Decision making systems are computer-based information systems which support knowledge management, decision making, and management reporting and assist managers in making decisions in highly uncertain and complex environments. As is known, when making decisions, people weigh up individual opinions and combine them through a thought process to come to a final informed decision. Olcer and Odabasi [21] proposed a new fuzzy multiple attribute decision making (FMADM) method which was suitable for multiple attributive group decision making (GDM) problems in a fuzzy environment to deal with the ranking and selecting an implemented Web-based consensus support system that was able to help or even replace the moderator in a consensus process in which experts are allowed to provide preferences using one of many types (fuzzy, linguistic and multigranular linguistic) of incomplete preference relations. In Fang's study [9], a comprehensive decision support system based on existing and new research developments in the conflict resolution graph model, the GMCR II, was developed for the systematic study of real-world interactive decision problems.

The Central Issues of Proceedings Volume I

Literature mining is indispensable in determining the most pertinent scientific research, especially in areas of particular interest such as geothermal utilization [23]. Literature mining has proven to be a powerful method for revealing major trends in published scientific literature across the years to allow for topic maps to be built [8]. NodeXL, a free analysis tool, was designed to facilitate the learning of the concepts and methods of social network analysis using visualization as a key component [13]. It is a powerful and easy-to-use interactive network visualization tool that leverages the widely available Microsoft Excel application as a platform for representing generic graphical data, performing advanced network analyses and providing a visual exploration of the networks. NodeXL generally supports multiple social network data providers who import graphical data (nodes and edge lists) into an Excel sheet, and has also been widely used by researchers [16, 22]. NodeXL, therefore, plays a vital role in the analysis of keyword trends in our research. A research documentation metasynthesis method is shown in Fig. 1.

This year, 140 papers were accepted, which were divided into two proceedings volumes of 70 papers each. To reveal the range of research topics in the accepted papers in proceedings Volume I, NodeXL was applied. The significance of keywords lies not only in the frequency or ratio but also in the keyword connections, which demonstrate how these papers revolve around the management science (MS) theme. The field of MS provides a set of concepts and metrics to systematically study the relationships between the keywords. Information visualization methods have also been proven valuable in assisting us in discovering patterns, trends, clusters, and outliers, even in complex social networks. In other words,

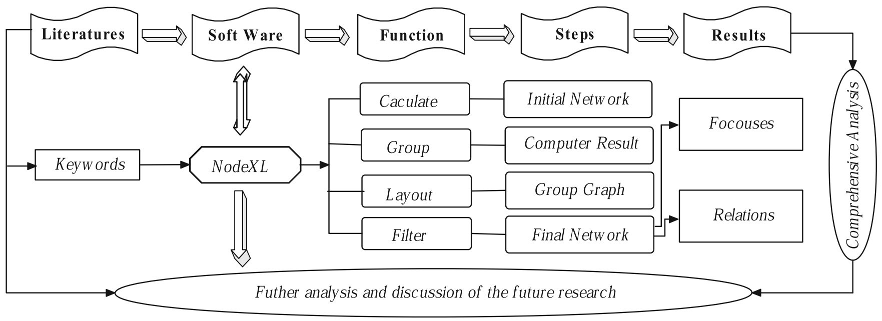


Fig. 1 Research documentation metasynthesis method

keywords are an important issue in MS. The network representing the relationship between the keywords is shown in Fig. 2.

The central issues of the Tenth ICMSEM proceedings Volume I are intelligent systems, computing methodology, information technology and decision-making systems. In the Intelligent Systems part, Jimnez et al. present a novel approach based on the employment of a neuronal network for signal processing to effectively determine pipe temperatures using only ultrasonic transducers. Ali and Kamran utilize the maximum benefit of technology to solve student traditional fee-paying issues by adopting a mobile banking system for a university. Guo proposes an integrated storage and distribution system design scheme in which electronic business enterprises self-build or rent distribution centers and unify the management and dispatch of the sellers' goods. Hu et al. provide theoretical and technical support for a warehousing slotting optimization system based on the different turnover rates for goods.

In the Computing Methodology part, Zhang et al. give a comprehensive introduction to the air drilling principle and the causes of air drilling accidents and propose an improved particle swarm algorithm for fuzzy neural network optimization based on new developments in automation and intelligent technology to illustrate its effectiveness. Shen et al. combine the ELECTRE-III method with intuitionistic fuzzy information in an integrated approach to solve a multicriteria

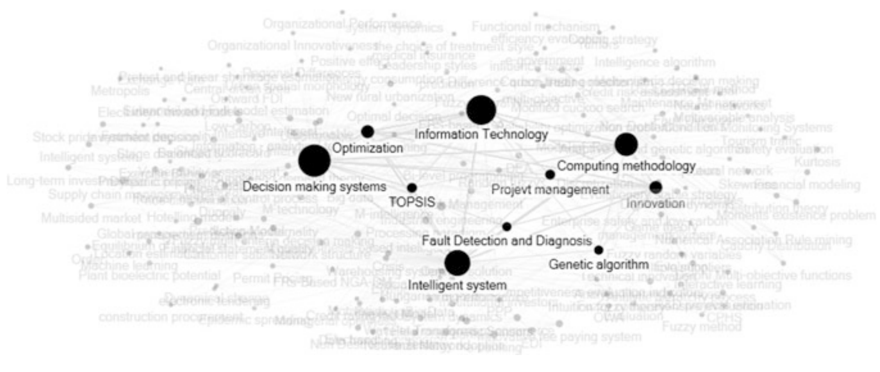


Fig. 2 Research topics in EM for the Tenth ICMSEM

decision making problem. Marugn et al. present a novel statistical methodology for the multi-variable analysis of big data from wind turbines, which filters the main parameters from the collected signals and uses advanced computational techniques to evaluate and give meaning to the data. Li and Ding concentrate on a safety evaluation of tourism traffic, establish an index system and develop a BP neural network model to solve the problem.

The Information Technology section also presents some innovative work. Moath Alyahya and Panuwatwanich present an e-Tendering model for public construction contracts (PCC) in Saudi Arabia to improve efficiency, which was developed using background information obtained from interviews, a focus group and a questionnaire conducted on personnel from the Saudi Arabian construction industry. Zeng et al. establish a metasynthesis-based intelligent big data processing paradigm methodology to achieve intelligent data acquisition, data identification, data structure design, data analysis, and to allow for automatic and intelligent decision making based on integrated big data processing technologies, decision making modeling methods, and intelligent algorithms. Jiang et al. develop a dissemination network topology using UCINET software and then analyze the network structure, role and position based on a Weibo users' directional adjacency matrix, the results from which found that the Weibo public opinion dissemination network has obvious complex network characteristics such as a scale-free property and a small world effect.

In the Decision Making Systems section, Tu et al. develop a bi-level model with multiple followers to make decisions on water resources allocation, in which the water shortage control objective is considered by the leader and the cost saving objectives are considered by the followers. In the model, random fuzzy variables are considered, which are transformed to determined variables using an expected value operator to make the model calculable. Nazim et al. explore the effects of leadership styles (Transformational, Transactional and Laissez-Faire Leadership) on organizational performance under the mediating role of organizational innovativeness (Process, Product and Marketing Innovativeness). Tang et al. used descriptive statistics, correlation analyses and logistics regression analyses to study VCI preferences for specific founder personalities based on data from GEM companies.

Development Trends for MSEM and ICMSEM

In this section, a review of MSEM is presented as a summary of past research approaches with an aim to understanding their effects on future MSEM research and practice. We hope to answer three research questions: (1) What are the MSEM development trends showcased about the four issues? (2) Does ICMSEM research coincide with the trends in the international journals about MSEM? and (3) What is the future of MSEM? For a systematic review, in this study, the research method used herein is similar to the one presented by Kitchenham [14], Kitchenham et al. [15], with demands placed on research questions, identification of research, selection process, appraisal, synthesis and inferences. The fundamental factor that distinguishes a systematic review from a traditional review of the literature is its comprehensive and unbiased search. In order to answer the three questions, our following review is based on the 490 papers in ICMSEM and the 3294 appeared in MSEM journals.

Indentification of Relevant Research
The fundamental factor that distinguishes a systematic literature review from a traditional literature review is in the comprehensive and unbiased search. In order to answer three questions, we reviewed all papers included in the proceedings of ICMSEM and the relevant research papers in MSEM journals.

To review all MSEM research, it is necessary to first identify the MSEM research terms and keywords. In this study, three electronic bases were considered (see Table 1) We started with a systematic search to identify MSEM research based on the two basic keywords, management science and engineering management. For an effective search, we chose a further 22 terms, 11 for each keyword, to identify MSEM research papers (Table 2). Then, we conducted a secondary search based on the references found in our primary studies and also refined the search terms. For example, to identify papers on heuristic algorithms, we used all of following terms: genetic algorithms, ant colony optimization, particle swarm optimization, simulated annealing, the bee algorithm and the metaheuristics algorithms. To avoid missing any important research, additional searches were performed directly on key journals and authors.

Synthesizing the research results found in the MS and EM existing literature and the MSEM characteristics, the MSEM development trends were summarized, as shown in Fig. 3.

Table 1 Sources of systematic reviews

Source	Address
Web of science	http://isiknowledge.com
EI compendex	http://www.engineeringvillage.com
Science direct	http://www.sciencedirect.com

Table 2 The main keyword used in the literature selection

Terms for	Terms for
Management science	Engineering management
Information technology	Civil engineering
Project management	Construction engineering
System engineering	Waste management
Evaluation and forecast	Electric power
Industry engineering	Ecological engineering
Risk management	Agricultural engineering
Heuristics Algorithms	Aviation and Aerospace Industry
Knowledge Management	Sofeware Engineering
Organization Behavior	Materials Engineering
Supply Chain	Transprotation Systems

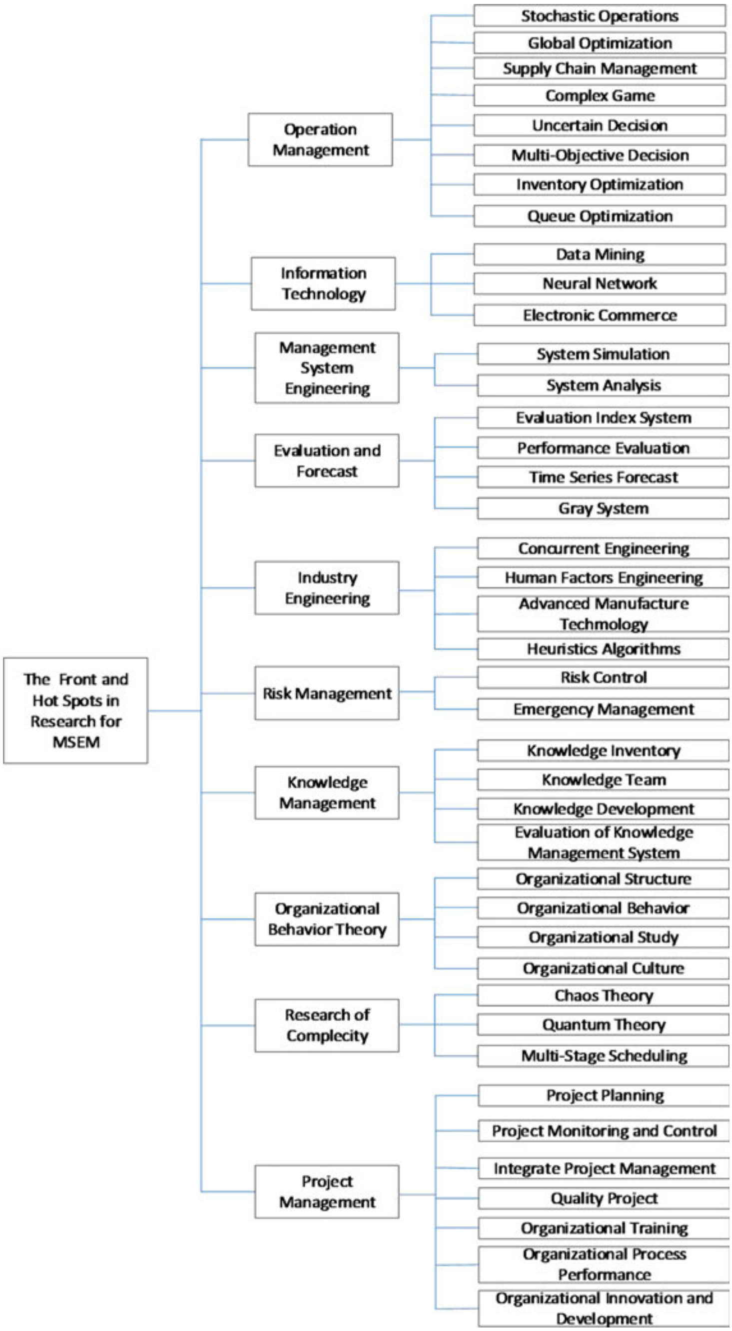


Fig. 3 The trend of development for MSEM

All these research areas are significant MSEM concerns and, as the MSEM development trend broadens over time, all are playing an important research role. The development trends show the clear MSEM research prospects; however more development in these areas is needed to provide greater contributions to management theory and engineering practice. More contributors, research results and academic platforms for communication, collaboration and advancement are also needed.

Survey to Articles in ICMSEM

We also surveyed the development trends in the last four ICMSEM. For this, it was necessary to review the articles published in the proceedings of the last four ICMSEM, which had 90, 130, 138, and 132 papers, respectively. From the analysis, an upward development momentum trend was revealed. In fact, in the past 10 years, there has been a rapid development in the field of MSEM in both theoretical and methodological research, the applications from which have close connections with reality. With the rapid development of computer and information science, there has been a great deal of research on MS under an EM background that harnesses the power of information technology, computers and networks. Therefore, following this trend, the articles published in all four proceedings were divided into papers using these technologies and papers not using these technologies.

Figure 4 shows the article distribution, from which we can see that most papers fell into the first category with more research using information technology or computer networks. It can also be seen that many more academics are conducting research within the MSEM frame that emphasizes actual management backgrounds, effective theories and methods, as well as innovative engineering practice. From the analysis of MSEM engineering practice, the distribution of the articles for the 22 engineering fields is shown in Table 3.

As for ICMSEM proceedings in this year, Jimnez et al. present a novel approach based on signal processing employing neuronal network to determine effectively the temperature of pipe, using only ultrasonic transducers. Ahmed et al. propose a new method of generating classes of distribution functions through convolution of smooth and non-smooth characteristic functions where the smoothing parameter is

Fig. 4 The distribution of the articles in ICMSEM according to the two types for MSEM

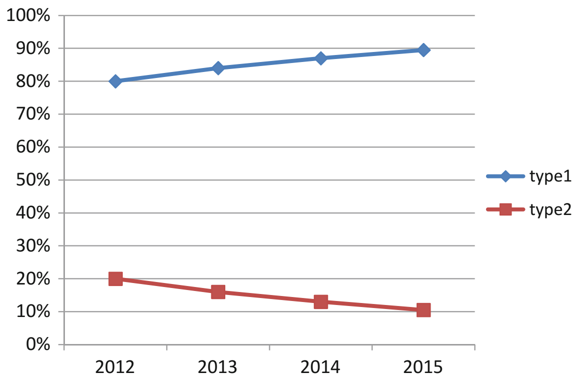


Table 3 The distribution of the articles published in the proceedings of ICMSEM according to the engineering fields

Engineering fields	2012	2013	2014	2015	2016
Aerospace	3	5	4	5	4
Intelligent	3	8	13	16	15
Software	6	7	9	8	7
Computer	6	12	14	13	13
Information	7	15	16	17	18
Communications	4	6	6	7	5
Data	9	14	16	15	18
Network	7	8	6	7	8
Ecology	4	3	4	4	4
Construction	3	4	5	2	3
Transportation	2	4	2	3	2
Systems	4	5	4	6	4
Manufacturing	5	7	6	5	6
Safety	4	4	7	5	8
Finance	1	3	2	4	3
Agriculture	2	2	3	2	2
Power	2	3	3	2	2
Energy	1	1	2	1	1
Vehicular	3	3	2	3	3
Signal	1	2	1	2	2
Materials	2	3	1	2	2
Hydropower	2	1	3	1	2
Aviation	2	3	3	2	2
Logistics	2	4	5	3	3
Tourism		3	1	3	3

used to control the thickness of the density tails. Liao et al. not only demonstrate that the shortage retailer can distort the actual shortage number to improve it profit, but also identify when to use underreporting or overreporting policy. All of their studies involve hot subjects of MSEM, leading MSEM towards a more in-depth development field.

In conclusion, two trends became apparent from the analysis of the last four ICMSEM proceedings; (1) An increasing number of academics are doing research under an MSEM framework that emphasizes actual management backgrounds, effective theories and methods as well as innovative engineering practice and (2) A wider range of engineering fields are becoming involved. All in all, it can be seen that ICMSEM research reflects the current MSEM development trends. Moreover, the ICMSEM has taken the lead in some areas such as ecological engineering, aviation engineering and safety engineering. This present research vitality will hopefully result in a new round of research in the coming years.

Conclusion

In this paper, we briefly introduced the four issues covered in the proceedings Volume I and summarized the previous research in the last four issues. By itemizing the main studies in this year's ICMSEM Proceedings Volume I, we highlighted the four central issues and identified the most prominent topics this year. Finally, we analyzed the MSEM and ICMSEM development trends, identified the issues that the MSEM journal should focus on and detailed the ICMSEM expectations for the future.

References

1. Ackoff RL (1962) Scientific method: Optimizing applied research decisions
2. Alonso S, Herrera-Viedma E et al (2010) A web based consensus support system for group decision making problems and incomplete preferences. Inf Sci 180(23):4477–4495
3. Ash JS, Berg M, Coiera E (2004) Some unintended consequences of information technology in health care: the nature of patient care information system-related errors. J Am Med Inform Assoc 11(2):104–112
4. Bates DW, Evans RS et al (2003) Detecting adverse events using information technology. J Am Med Inform Assoc 10(2):115–128
5. Beged-Dov AG (1967) An overview of management science and information systems. Manage Sci 13(12):B–817
6. Bhatt GD, Grover V, Grover V (2005) Types of information technology capabilities and their role in competitive advantage: An empirical study. J Manage Inf Syst 22(2):253–277
7. Cooper LG, Giuffrida G (2000) Turning datamining into a management science tool: New algorithms and empirical results. Manage Sci 46(2):249–264
8. De Bruijn B, Martin J (2002) Getting to the (c) ore of knowledge: mining biomedical literature. Int J Med Informatics 67(1):7–18
9. Fang L, Hipel KW et al (2003) A decision support system for interactive decision making-part i: model formulation. Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on 33(1):42–55
10. Gregor S, Benbasat I (1999) Explanations from intelligent systems: Theoretical foundations and implications for practice. MIS quarterly pp 497–530
11. Gross T (2010) Towards a new human-centred computing methodology for cooperative ambient intelligence. J Ambient Intell Human Comput 1(1):31–42
12. Hall AD (1962) A methodology for systems engineering
13. Hansen D, Shneiderman B, Smith MA (2010) Analyzing social media networks with NodeXL: Insights from a connected world. Morgan Kaufmann
14. Kitchenham B (2004) Procedures for performing systematic reviews. Keele, UK, Keele University 33(2004):1–26
15. Kitchenham B, Mendes E, Travassos GH (2006) A systematic review of cross-vs. within-company cost estimation studies. In: Proceedings of the 10th international conference on Evaluation and Assessment in Software Engineering, British Computer Society, pp 81–90
16. Kumar S, Jan JM (2012) Discovering knowledge landscapes: An epistemic analysis of business and management field in Malaysia. Procedia-Social Behav Sci 65:1027–1032
17. Lee J, Chiang HD (2004) A dynamical trajectory-based methodology for systematically computing multiple optimal solutions of general nonlinear programming problems. Automatic Control, IEEE Transactions on 49(6):888–899

18. Lewis W, Agarwal R, Sambamurthy V (2003) Sources of influence on beliefs about information technology use: An empirical study of knowledge workers. MIS Quarterly pp 657–678
19. Lin HC (2007) Intelligent neural network-based fast power system harmonic detection. Industrial Electronics, IEEE Transactions on 54(1):43–52
20. Luo JX, Shao HH (2006) Developing soft sensors using hybrid soft computing methodology: a neurofuzzy system based on rough set theory and genetic algorithms. Soft Computing 10(1):54–60
21. Ölçer A, Odabasi A (2005) A new fuzzy multiple attributive group decision making methodology and its application to propulsion/manoeuvring system selection problem. Eur J Oper Res 166(1):93–114
22. Parr CS, Guralnick R et al (2012) Evolutionary informatics: unifying knowledge about the diversity of life. Trends Ecol Evol 27(2):94–103
23. Scherf M, Epple A, Werner T (2005) The next generation of literature analysis: integration of genomic analysis into text mining. Brief Bioinform 6(3):287–297
24. Venkatesh V, Morris MG et al (2003) User acceptance of information technology: Toward a unified view. MIS quarterly pp 425–478
25. Wang FY (2010) Parallel control and management for intelligent transportation systems: Concepts, architectures, and applications. Intelligent Transportation Systems, IEEE Transactions on 11(3):630–638
26. Zilberstein S (1996) Using anytime algorithms in intelligent systems. AI Mag 17(3):73

Advances in Industrial Engineering, Logistics Engineering, Project Management and Risk Management Based on the Tenth ICMSEM Proceedings

Jiuping Xu

Abstract The advances in management science and engineering management (MSEM) have contributed to developments in society and the economy, especially in the management and control fields. First we introduce the Tenth ICMSEM Proceedings Volume II, describe the basic MSEM concepts and then review developments in the four key issues covered in the proceedings Volume II. Then, we review research from industrial engineering (IE), logistics engineering (LE), project management (PM) and risk management (RM), summarize the key research achievements in the four areas covered in Volume II and examine the research trends from MSEM journals and the ICMSEM. We are committed to providing an international forum for academic exchange and communication through the ICMSEM and plan to continue our innovative MSEM progress in the future.

Keywords Industrial engineering · Logistics engineering · Project management · Risk management

Introduction

MSEM, which is a combination of MS and EM, emphasizes the theories, methods, and engineering practices behind complex management decision making. The diverse MSEM research directions in the last decade have brought new vitality to management and engineering practice. Through the continuing and expanding development of innovative managerial tools, MSEM has significantly influenced both domestic and international economic development. MSEM is by nature a synthesis, so has a broad research focus that combines complex management

J. Xu (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: xujiuping@scu.edu.cn

theories and practical engineering solutions to successfully solve management practice problems. The MSEM research field is cross-functional and multidisciplinary, so effectively supports real-world management execution and control.

Engineering management (EM) describes functional or project management technical engineering professionals working in product development, manufacturing, construction, design engineering and industrial engineering. In Kocaolgu's definition, EM is a field which examines engineering management through comprehensive scientific research to develop innovative engineering solutions which can improve technical organization, technical resources and technical systems [9]. With a development history of 30 years, EM is a practical management system which has been playing an increasingly important role in modern management developments. Volume II of the proceedings focuses on four key MSEM areas: industrial engineering, logistics engineering, project management and risk management.

Literature Review

Literature reviews are useful in gaining insight into particular research fields and can assist in revealing new research directions. In this section, we present a literature review on developments in industrial engineering, logistics engineering, project management and risk management.

Industrial Engineering

Industrial engineering is often termed "Industrial and Systems Engineering" or "Industrial and Operations Engineering". Overall, however, IE is the branch of engineering that focuses on the optimization of complex processes or systems. Himmel et al. [13] review the scientific and technological developments aimed at improving the water disinfection and decontamination and examined the efforts being made to increase water supplies through the safe reuse of wastewater and the efficient desalination of sea and brackish water. Chiou and Tzeng [6] propose a fuzzy hierarchical analytic approach to determine the weighting of subjective judgments and developed a nonadditive fuzzy integral technique to evaluate a green engineering industry case as a fuzzy multicriteria decision making (FMCDM) problem. Hao et al. [12], through the application of intelligent software agents, Internet/Web, workflows and database technologies, conduct an industrial case study on the development of a collaborative e-engineering environment for mechanical product design engineering. Boks and Diehl [3] outline the challenges involved in integrating sustainability issues into a regular industrial design engineering product innovation course and pointed out that sustainability needs to encompass a wider scope so as to include social issues such as safety, which could enthuse staff and students with little sustainability knowledge, improve learning processes and result in higher credibility and acceptance.

Logistics Engineering

Logistics Engineering is dedicated to the scientific organization of the purchase, transport, storage, distribution, and warehousing of materials and finished goods. Focus in this field tends to be on the efficient and effective use of restricted resources to accomplish desired goals and objectives. Naim et al. [18] present a logistics systems and process and developed a template for a logistics education course that addressed functional, process and supply chain needs, which was consequently developed by a number of university partners with core skills in different disciplines. Chen [5] uses a Kansei engineering approach and a logistics regression technique to analyze three models based on the relationships between the service elements of international express and the customers' Kansei perceptions and usage intentions. White [24] focuses on next-generation research directions for productivity-control supply chains based on real-time data, and elucidated the effective extraction of information value. Ejim-Eze and Amadi-Echendu [8] examine how integrated logistics supply chains could influence organizational learning in automobile manufacturing firms in terms of collaboration, information sharing, cooperation, and technological transfer between developed country sources and partners or subsidiaries in developing countries where local content policies impose specific requirements.

Project Management

Project management (PM) is the planning, organizing, securing and management of resources to successfully complete specific project goals and objectives. Project management is used in manufacturing, construction, design engineering, industrial engineering, technology, production, and many other areas. PM research advances have addressed issues such as scheduling problems, water conflict problems and project cost control. Huchzermeier and Loch [14] develop a simple real option model for an R&D project, in which the market payoff and the operational variables of budget, product performance, market performance requirement, and scheduling were all subject to uncertainty. Pich et al. [21] identify three fundamental project management strategies: instructionism, learning, and selectionism; and demonstrated how these three strategies fit into modern PM methods. Cicmil et al. [7] propose a research approach that focused on practitioners' lived project experiences, explored the ontological, epistemological and methodological assumptions underlying this kind of research and provided examples of project management research that had originated from this perspective. Project management and project organization is a complex subject and needs to be examined from several perspectives. Soderlund [22] discuss emerging PM perspectives and also raise a number of questions that future project research should address.

Risk Management

Risk management (RM) is the identification, assessment, and prioritization of risks followed by a coordinated and economic application of resources to minimize, monitor, and control the probability and/or impact of unfortunate events or to maximize the realization of opportunities. RM includes transferring risk to another party by avoiding risk, reducing the negative effects of risk and accepting some or all of the consequences of a particular risk. Christopher and Tang [23] reviewed several quantitative models for supply chain risk management (SCRM) and related the strategies found with actual practice and found that the quantitative models were primarily designed for operational risk management rather than disruption risk management. Basak and Shapiro [2], using the Value-at-Risk (VaR), analyzed the optimal, dynamic portfolio and wealth/consumption policies of utility maximizing investors who needed to manage their risk exposure and found that VaR risk managers often optimally chose a larger exposure to risky assets than non-risk managers and consequently incurred larger losses when losses occurred. Ait-Sahalia and Lo [1] proposed a nonparametric VaR measure that incorporated an economic valuation based on a state-price density associated with underlying price processes. In the context of a representative agent equilibrium model, they constructed an estimator for the risk-aversion coefficient implied from joint observations of a cross-section of options prices and underlying asset value time-series.

The Central Issues of the Proceedings Volume II

A data collection module was used to interrogate the initial research database to obtain the most relevant information. Keywords are an important index for the identification of the essential content in research articles. The keywords in the 70 articles in Volume II were extracted to a new database to allow for a tendency

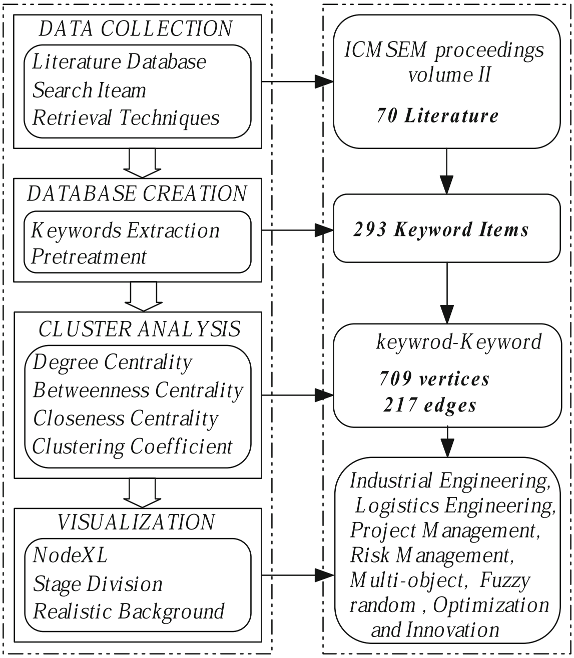


Fig. 5 DAS literature mining

analysis, and the organization of this data analysis system (DAS) is shown in Fig. 5 with the four sections shown on the left, and the analysis results on the right.

With EM as the key component, we used the open-source software tool NodeXL to facilitate the learning of the concepts and methods. To begin with, the keywords were processes and except for the unified expressions, keywords with the same meaning and words that included a similar meaning were unitized; for example, terms such as “Industrial engineering”, “Industry engineering” and “Industrial project” were unified under the main term “Industrial engineering”. This preliminary process reduced the number of keywords, making it possible to develop an efficient network. At the same time, the vertices’ shapes were set to determine the betweenness and closeness centrality. When the degree of a vertex’s betweenness and closeness centrality was beyond a certain value, the shape of this vertex was square. The aim of this analysis was to determine the key EM concepts that connected with other research topics through the primary nodes. From these steps, a network of keywords was developed to illustrate the important relationships, as shown in Fig. 6.

The above analysis of Volume II of the proceedings highlighted the core contents; industrial engineering, logistics engineering, project management and risk management. In the Industrial Engineering section, Li et al. investigate the cointegration relationship between industrial economic growth and environmental pollution in Sichuan Province and further test the Granger causality using three typical pollution indicator time-series’ data. Nagiev and Nagiyev demonstrate that problems can be reduced with the introduction of a certain feedback structure that stabilizes the relationship between the optimality and reachability criteria weight coefficients during a process with a termination time. For problems with a prolonged control interval, when an arbitrary random signal conveys its statistical parameters, the programmed control of the optimality and reachability criteria weight coefficients can more reliably guarantee process optimality. Akhmedov et al. propose a dynamic interactive process simulation to describe the functioning of complicated objects in conditions of indeterminacy, and present fuzzy net Petri type V_f dynamic process models.

Logistics Engineering section primarily covers logistics and supply chain problems. Asaf et al. examine stochastic vertical transportation (lift) system

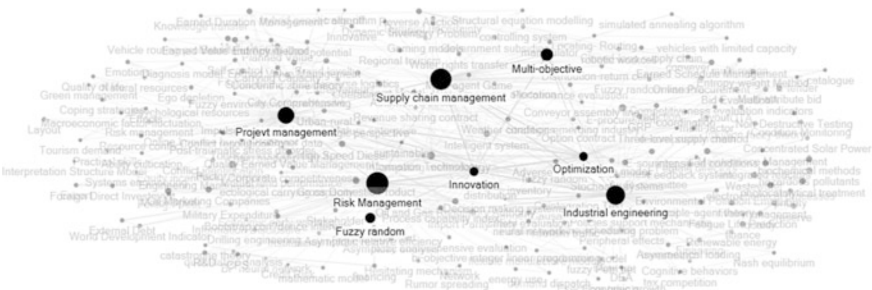


Fig. 6 Research topics in EM for the Tenth ICMSEM

mathematical models with arbitrary values for customer intensity to introduce and compare system control strategies. Hua and Song construct a three-level green supply chain system that includes manufacturers, suppliers and customers, and analyzes the decision making and profit incentive mechanisms for the supply chain members. Sun and Guo use a robust optimization method to study the construction and design of a multi-objective dual-channel fresh produce supply chain network. By assigning different weights to the economic, environmental and customer satisfaction targets, a rational supply chain network distribution under different weather circumstances is determined, which is further demonstrated through the use of numerical examples. Nazam et al. propose a hybrid methodology based on the analytical hierarchy process (AHP) and the technique for order preference by similarity to ideal solution (TOPSIS) under a fuzzy environment for the selection and evaluation of reverse logistics operating channels.

The third part in Volume II focuses on developments in project management. Fausto et al. explore EVM methodology and propose a model to manage aerospace engineering projects based on a real case study. The model inputs are planning and monitoring; hence in the case study, the planned value, earned value and actual cost of aerospace projects are included. Based on 8000 patient data records from an investigation and survey of hospitals on three levels in Sichuan Province, Luo et al. use an interpretation structure model (ISM) to analyze the results of the factor relationships between patients and hospitals. Song et al. focus on a specific dam construction project to identify potential conflicts and analyze the root causes and mutual relationships. Based on the identified conflicts and a basic conflict management mechanism, a CTF layout framework is proposed to identify the CTF layout alternative that has the least conflicts between the CTF layout and other pre-planning tasks.

Risk management is important in all organizations and enterprises. Li et al. investigate the relationship between mutual fund rankings and fund managers' risk behavior and find that fund managers' risk adjustment behavior is affected by the market situation, with managers substantially adjusting fund risks in market downturns. Using the debt ratio to assess local government debt risk and determining fiscal expenditure efficiency using envelopment analysis data (DEA), Wang et al. examine the impact of local government debt risk on economic growth. Ahmed and Kamran evaluate the impact of military spending on external debt in highly indebted and low-income developing countries. Using a dummy variable technique, the effect of military spending on the external debt of individual countries is also analyzed. To avoid subjective assessments and allow for an objective system to explore the social risks, Li et al. investigate the problem of applying catastrophe theory to social risk assessment by determining the potential indices known as crashes.

Evaluation to ICMSEM and Development Trends of MSEM

In this section, we evaluate the last four ICMSEM to validate that the research trends are in line with the trends emerging in current MSEM journals.

Evaluation to ICMSEM

MSEM is a multidisciplinary field with a wide range of research areas focused on a combination of management theory and engineering practice; hence has successfully solved many problems associated with management practice functions. Therefore, it is essential that future research be in line with actual emerging management problems. From our review, we noticed that industrial engineering, ecological engineering, computer engineering, logistics engineering and risk management were the primary research foci for MSEM. Based on the findings in the ICMSEM, green supply chains, project management and financial engineering are necessary for future research. Further, the identification of appropriate and advanced management methodologies could help researchers solve practical problems.

Table 4 shows the distribution of the articles in MSEM journals with respect to the research methods found in ICMSEM. The most common methodologies used in MSEM journals have been simulation, optimization, mathematical models, game theory, network analysis, heuristic methods, system analysis and uncertainty theory, which are consistent with the eight popular methods in the findings from the ICMSEM. In both the ICMSEM and MSEM journals, the most common method was mathematical models.

In addition, 24 major engineering practice fields were identified in the MSEM journals, as shown in Fig. 7. Construction engineering and waste engineering have received the most attention with more than 250 papers in our database. Also 13 other fields had more than 100 papers each, so could be considered the primary engineering practice fields in the MSEM journals.

The Development Trends of MSEM

In this section, we evaluate the MSEM development trends and determine whether these trends are in line with the MSEM journal trends.

A comparison of the documents in MSEM journals found that there were commonalities between the ICMSEM and MSEM journals (see Fig. 8). In both the ICMSEM and MSEM journals, more than 50 % of the research papers emphasized

Table 4 The distribution of the article according to management methodologies

Methods	Numbers	Methods	Numbers
Simulation	254	Queuing theory	53
Optimization	325	Heuristic method	307
Mathematical model	397	Uncertain theory	348
Decision analysis	93	System dynamic	96
Data mining	79	System analysis	216
Game theory	182	System thinking	53
Probability and statistics	81	Multi-methodology	49
Markov analysis	44	Interactive planing	20
Network theory	158	Strategic choice approach	28
Total system intervention	21		

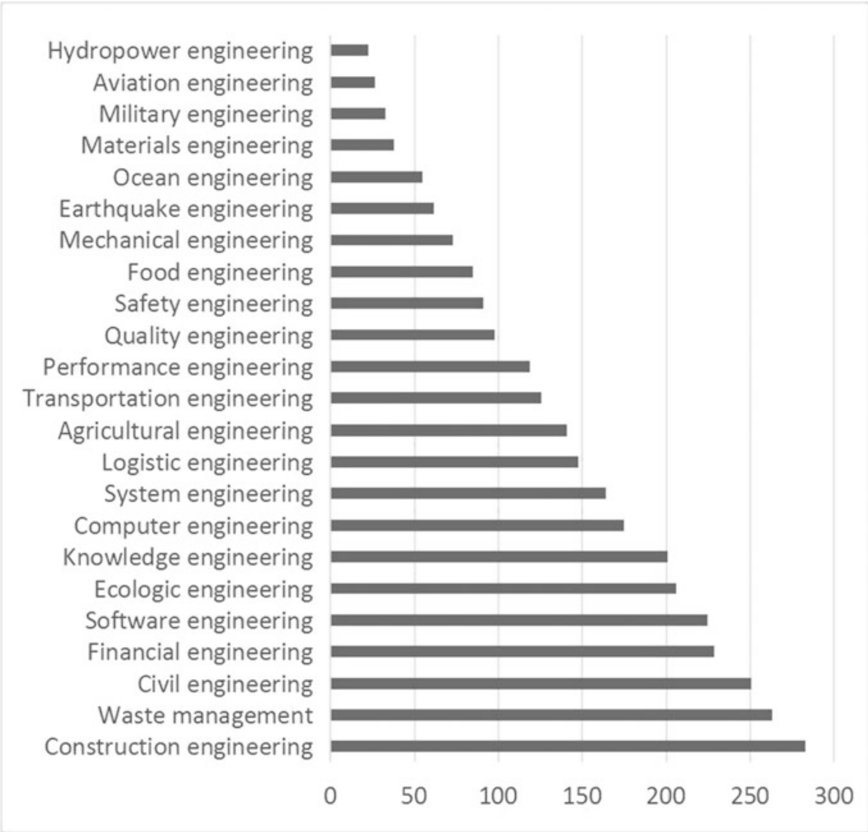
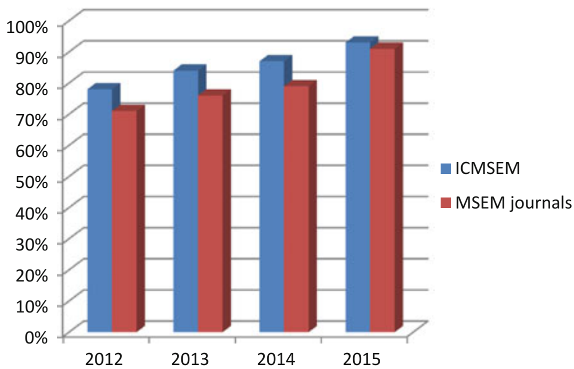


Fig. 7 The number of articles in main fields of engineering practice

Fig. 8 Comparison between ICMSEM and MSEM journals according to the research type 1



the management use of information technology or computers and networks. It can be seen that as more academics become interested in MS research, the focus on the use of information technology or computers and networks (i.e., appropriate management science methodology) under an EM background (i.e., practical engineering problem) indicates that excellent research momentum is developing in EMEI.

To review the reach of MSEM research, it was necessary to identify the search terms and keywords. We started with a systematic search to identify MSEM research based on the two basic keywords, management science and engineering management. A secondary search was then conducted based on the references found in the primary studies, from which the search terms were refined. For example, to identify papers on heuristic algorithms, the following terms were used: genetic algorithms, ant colony optimization, particle swarm optimization, simulated annealing, the bee algorithm and metaheuristics algorithms.

In MSEM research, it is very important to link theory with practice. Practical research focusses on the framework of the problem and stresses that we make full use of existing knowledge, theories, methods and techniques to analyze the problem framework, and apply model techniques to establish integrated models. Theoretical research focusses on nonrepresentational MSEM problems such as concrete management problems. It is necessary to establish theoretical systems by making use of existing knowledge and theories to establish conceptual models, physical models and mathematical models with concluding theories and principles. For example, a new class of problems, the VRPTW has been developed which can be defined as; after a given set of depots, a homogeneous fleet of vehicles and a set of known demand locations, a set of closed routes needs to be found which originate and end at the depots to service all demands to minimize travel costs, while the service at each demand point must start within an associated time window [20, 26].

Xu [25] proposed 12 main engineering fields; construction, ecology, logistics, finance, computers, software, performance, knowledge, transportation, aviation, tourism and safety. All 12 fields are covered in these tenth conference proceedings and some new fields such as earthquake engineering have also appeared. In addition, information and intelligent engineering are a highlight in these proceedings. Aviation engineering is a branch of engineering behind the design, construction and science of aircraft and spacecraft [4] and has many elements such as control engineering, materials science, fluid mechanics, electrotechnology and risk and reliability [11]. Of these, risk has become an important focus, especially in the civil aviation industry [16]. In our proceedings, there are many papers related to civil aviation risk analysis. Further, safety engineering is an applied science strongly related to systems engineering and the subset system safety engineering. Safety engineering assures that life-critical systems behave as needed even when other elements fail. Safety engineering theories have been applied to many fields including operator management, traffic control, aviation, food engineering, software engineering and accident analysis [10, 15, 17].

In this year's ICMSEM proceedings, by modeling a behavior of such systems on a computer and getting numerical results for different efficiency indexes and characteristics, Asaf et al. compared various control policies to derive the optimal.

Duarte et al. presented green and lean model for business sustainability and indicators for an efficient and discussed green business. Shibli Rubayat Ul Islam' and Mohammad Tareq's work lie in the fact that most people in Bangladesh are outside the traditional banking service and these people are now using banking service through mobile banking; however, this area of research is untapped yet. Their researches are the forefront of MSEM and can give us some inspiration in this field.

We believe that the MSEM should focus on the study of concrete EM problems and the popularization of MS knowledge. "Investigations aimed at applications and technological advances should be incorporated". We can apply theory to solve concrete problems and achieve theoretical breakthroughs for new MS problems. Excellent academic research can affect developments across the world, but further focus on regional areas is also needed. To ensure a bright MSEM future, there is a need for inspiration, practical theories, effective methods and extensive applications in future developments. To achieve this, MS knowledge needs to be popularized, which is the duty of all MSEM academics.

Conclusion

Based on the four issues covered in the Tenth ICMSEM Proceedings Volume II, we summarized the key research areas. We also presented research from the previous year and used the open-source software tool NodeXL to illuminate the key EM concepts. To analyze the MSEM and ICMSEM development trends, we identified the main search terms and keywords. Our key objective is to continue to improve the quality of the papers to be published in the proceedings and to ensure that the organization of ICMSEM is dynamic and appealing to MSEM researchers worldwide. MSEM research is continuously developing and new trends are appearing every year. However, more research is necessary so as to popularize MSEM developments to provide a more active research forum.

References

1. At-Sahalia Y, Lo AW (2000) Nonparametric risk management and implied risk aversion. J Econom 94(1):9–51
2. Basak S, Shapiro A (2001) Value-at-risk-based risk management: optimal policies and asset prices. Rev Financ Stud 14(2):371–405
3. Bhatt GD, Grover V, Grover V (2005) Types of information technology capabilities and their role in competitive advantage: An empirical study. J Manage Inf Syst 22(2):253–277
4. Blockley R, Shyy W (2010) Encyclopedia of aerospace engineering. Encyclopedia of Aerospace Engineering
5. Chen MC, Chang KC et al (2015) Applying a kansei engineering-based logistics service design approach to developing international express services. International J Phys Distrib Logist Manage 45(6):618–646

6. Chiou HK, Tzeng GH (2002) Fuzzy multiple-criteria decision-making approach for industrial green engineering. Environ Manage 30(6):0816–0830
7. Cicmil S, Williams T et al (2006) Rethinking project management: researching the actuality of projects. Int J Project Manage 24(8):675–686
8. Ejim-Eze E, Amadi-Echendu J (2015) Sustaining engineering logistics processes via organizational learning. In: Industrial Engineering and Operations Management (IEOM), 2015 International Conference on IEEE, pp 1–7
9. Farr JV, Buede DM (2003) Systems engineering and engineering management: Keys to the efficient development of products and services. Eng Manage J 15(3):3–9
10. Grunske L, Kaiser B, Reussner RH (2005) Specification and evaluation of safety properties in a component-based software engineering process. In: Component-Based Software Development for Embedded Systems, Springer, pp 249–274
11. Gruntman M (2007) The time for academic departments in astronautical engineering. In: AIAA SPACE 2007 Conference & Exposition Agenda
12. Hao Q, Shen W et al (2006) Agent-based collaborative product design engineering: an industrial case study. Comput Ind 57(1):26–38
13. Himmel ME, Ding SY et al (2007) Biomass recalcitrance: engineering plants and enzymes for biofuels production. Science 315(5813):804–807
14. Huchzermeier A, Loch CH (2001) Project management under risk: Using the real options approach to evaluate flexibility in R&D. Manage Sci 47(1):85–101
15. Kletz T (1991) An engineer's view of human error, (institution of chemical engineers, rugby, UK)
16. Lee WK (2006) Risk assessment modeling in aviation safety management. J Air Trans Manage 12(5):267–273
17. Lutz RR (2000) Software engineering for safety: a roadmap. In: Proceedings of the Conference on the Future of Software Engineering, ACM, pp 213–226
18. Naim M, Lalwani C et al (2000) A model for logistics systems engineering management education in europe. Eur J Eng Educ 25(1):65–82
19. Norrman A, Jansson U (2004) Ericsson's proactive supply chain risk management approach after a serious sub-supplier accident. Int J Phys Distrib Logist Manage 34(5):434–456
20. Pavone M, Bisnik N et al (2009) A stochastic and dynamic vehicle routing problem with time windows and customer impatience. Mobile Network Appl 14(3):350–364
21. Pich MT, Loch CH, Meyer AD (2002) On uncertainty, ambiguity, and complexity in project management. Manage Sci 48(8):1008–1023
22. Söderlund J (2004) Building theories of project management: past research, questions for the future. Int J Project Manage 22(3):183–191
23. Tang CS (2006) Perspectives in supply chain risk management. Int J Prod Econ 103(2): 451–488
24. White III CCC (2008) Trends and research directions in supply chain & logistics engineering. In: Service Operations and Logistics, and Informatics, 2008. IEEE/SOLI 2008. IEEE International Conference on IEEE, vol 2, pp XII–XII
25. Xu J, Nickel S et al (2015) Proceedings of the Ninth International Conference on Management Science and Engineering Management, vol 362. Springer
26. Yang YQ, Xu JP (2008) A class of multiobjective vehicle routing optimal model under fuzzy random environment and its application. World J Modell Simul 4(2):112–119

Part I
Intelligent Systems

Chapter 1
A Condition Monitoring System for Blades of Wind Turbine Maintenance Management

Isaac Segovia Ramirez, Carlos Quiterio Gómez Muñoz and Fausto Pedro García Marquez

Abstract Wind energy is one of the most competitive and efficient renewable energy. It requires an efficient management system to reduce costs, predict failures and increase the production. The main objective of this paper is to design the appropriate tests and develop a condition monitoring system (CMS) to display the surface temperature of any body state using infrared radiation. The data obtained from this system lead to identify the state of the surface. The CMS is used for maintenance management of wind turbines because it is necessary an effective system to display the surface temperature to reduce the energy losses. This paper analyses numerous scenarios and experiments on different surfaces in preparation for actual measurements of blade surfaces.

Keywords Maintenance management · Fault detection and diagnosis · Infrared sensors · Non-destructive tests · Wind energy

1.1 Introduction

The renewable energy industry is undergoing continuous improvement and development worldwide. This industry requires high levels of reliability, availability, maintainability and safety (RAMS) for wind turbines [2, 3, 11, 12, 15]. Condition monitoring (CM) is defined as the process of determining the condition of system [4, 10]. The objective of this work is to detect ice or other disturbing element on the surface of the wind turbine blade. A thermal infrared sensor is used to measure the radiance emitted by the blade surface.

The process of obtaining thermal information cannot be easy because there are situations where it is unfeasible take conventional measurements. For this reason, it is impossible to use devices based in direct contact. Data acquisition using infrared thermography is an increasing technique used due to its speed, efficiency and

I.S. Ramirez · C.Q.G. Muñoz · F.P.G. Marquez (✉)
Ingenium Research Group, Castilla-La Mancha University, Ciudad Real, Spain
e-mail: FaustoPedro.Garcia@uclm.es

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_1

non-destructive nature. Nondestructive testing are those that do not affect the system and its properties remain constant after the measurement tasks [5–7, 13, 14]. Any type of material generates thermal energy that radiates outward due to a temperature gradient. Infrared thermography is based on heat transfer by radiation, capturing the infrared radiation emitted by bodies at different levels of the electromagnetic spectrum for temperatures, therefore there is no physical contact with the body in question and the properties or system conditions are not altered. This technology is quick and effective, and it is able to get reliable thermal data in different areas where traditional thermal sensors are unfeasible or physical contact is impossible [8].

The measurements made by infrared thermography display the surface temperature of the bodies, not the thermal state inside them. This is the major disadvantage of infrared thermography and, therefore, it is not possible quantify the thermal processes occurring within the surface of the measured bodies. Infrared emissions of the bodies are not visible to the human eye and it requires to use sensors that transform the infrared energy into electrical output [1].

1.2 Equipment

1.2.1 Sensor

To take acceptable data, it is essential to use a reliable sensor. Each of these sensors is formed by a thermopile that it will measure the surface irradiation, and a thermistor, which calculates the temperature of the sensor body. These two components provide an output signal in millivolts, that using equation adapted Stefan–Boltzmann [9] for each sensor. It is possible to transform this information into temperature values. These laws indicate that the transferred radiation is proportional to the fourth power of the absolute value temperature, being m y b adjustment coefficients provided by the manufacturer, S_D is the signal collected in millivolts and T_T total temperature in °C.

$$T_T = \sqrt[4]{T_D^4 + m \times S_D + b} - 273.15.$$

The sensor must define the temperature of the bodies inside the measuring area demarcated by a germanium lens of 8–14 µm and a field of view of 22°. Furthermore, it is able to provide temperature values with an error of ±0.2 °C when operating in a range of −10°–65 °C.

Figure 1.1 shows the response of this sensor in a given wavelength. The experimental values of the sensor and a black body shows an approximate range.

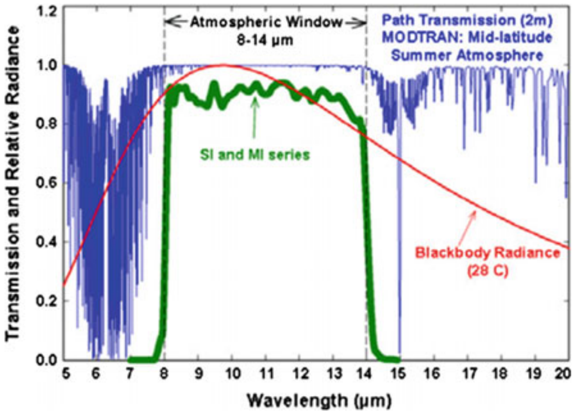


Fig. 1.1 Spectral response of radiometers [2]

1.2.2 Wireless Recovery Data

This equipment uses the sensor described previously but it is connected by radio waves to a wireless station with a datalogger that records and stores the collected data. The instrument employed is CWB100, and it is possible to analyses the data in real-time. Furthermore, it is possible to create a wireless network that can be adapted to the needs of measurement, changing the pattern and number of sensors. When the network is designed and programmed, the sensor starts to record data and get different variables: Tt (temperature sensor), Tb (body temperature sensor) and Ti (room temperature). It is useful to create a network capable to inspect several blades in real time (Figs. 1.2 and 1.3).

Fig. 1.2 Wireless sensor making measurements in pipe

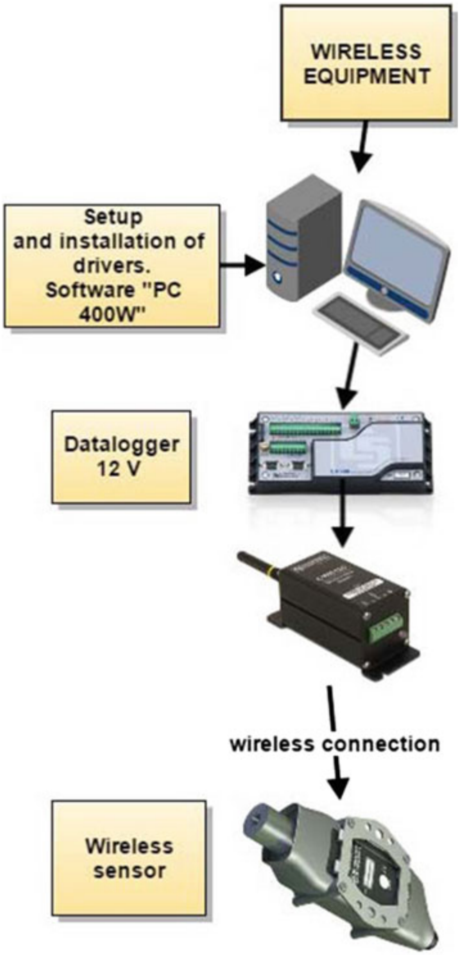


Fig. 1.3 Process diagram

1.3 Methodology

In order to check the reliability of the infrared sensor, a wind turbine section has been measured. The sensor is arranged such that the field of view encompasses the entire section of the blade.

1.3.1 Data Collection

To verify the reliability of the temperature data obtained by the sensor, different scenarios are considered in the experimental platform described above. The temperature data obtained in all the tests are:

- Th1: Temperature of the thermocouple 1.
- Th2: Temperature of the thermocouple 2.
- Tt: Temperature sensed by the sensor CWS220E.
- Tb: Temperature of the body CWS220E.
- Ti: Ambient temperature.

1.3.2 Experiments

Note that this sensor is ideal for inspecting curved surfaces (Fig. 1.4). The measurements of the blade section were taken at room temperature and the results are shown in Fig. 1.5.

Fig. 1.4 Wind turbine's blade employed in the experiments

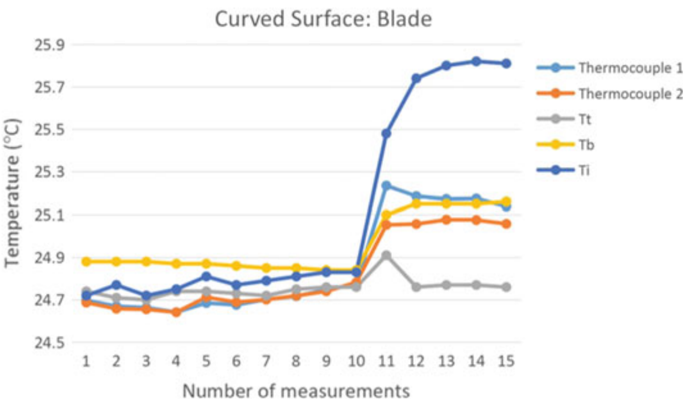


Fig. 1.5 Temperature of the blade with all the equipment

Fig. 1.6 Surface of the blade with aluminium

The results in Fig. 1.5 shows that the first measurements are almost constant until the ambient temperature increases drastically. This increasing caused the temperature of the object rises to rediscover thermal equilibrium. The measurements are recorded at long intervals of time, therefore the thermal values demonstrate stable values.

Experiments about variations in emissivity were also done. In order to highlight the emissivity of the elements, the system was coated with aluminum (Fig. 1.6) because this element has a very low emissivity. The main results are presented in Fig. 1.7.

Figure 1.7 shows that the ambient temperature increases again. Therefore, it is affecting the measurement system. In this case, the highlighted variable is the temperature measured by the wireless sensor, because this result is affected by the low emissivity value.

For the last experiment, the blade section was frozen, and the temperatures given by the thermocouple and by the infrared sensors where collected.

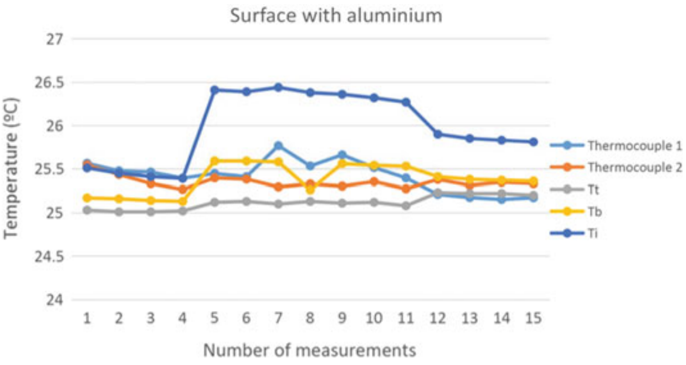


Fig. 1.7 Temperatures with all the equipment in surface with aluminium

1.3.3 State of the Surface

The state of the surface is one of the most important variables in the infrared thermography. The tests were taken in the same wind turbine blade section at different states. Temperatures collected on the surface of the previously blade are represented in Fig. 1.8. The data are affected by the emissivity of each surface. The experiments were carried out for three types of scenarios:

- Ambient temperature.
- Frozen surface without ice.
- Frozen surface with ice.

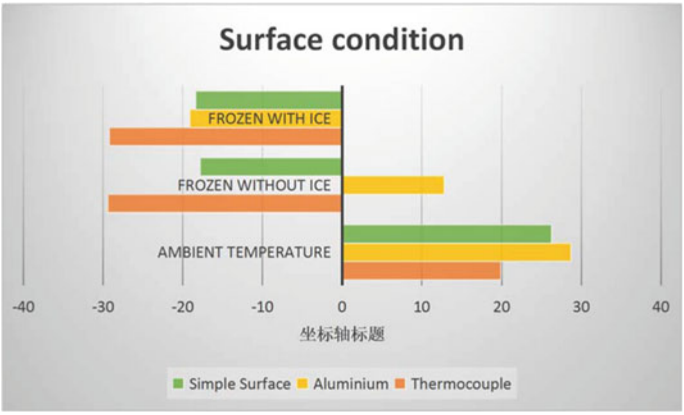


Fig. 1.8 Temperatures affected by the emissivities of the surfaces

Figure 1.8 shows that it is possible to distinguish between the 3 different states of the wind turbine blade employing a infrared sensor and with the help of a surface with low emissivity.

1.4 Conclusion

This paper presents a condition monitoring system employed to analyses the status of the blades' surfaces of the wind turbines, performance with wireless infrared sensor. This equipment has a very high accuracy, providing data with an error of $\pm 0.2\,^{\circ}\mathrm{C}$ if the data emissivity of the body to be inspected are adequate. This component has advantages over thermal imagers the low price and versatility to be configured. It is possible to identify each of the states considered in the blade in real time. In this work it has been able to distinguish between three states, which are: blade at room temperature; frozen blade without ice; and frozen blade with ice. In summary it is possible to determine temperature and superficial status of a piece.

Due to its speed, autonomy, efficiency and non-destructive nature, this type of testing is efficient for their use in wind energy maintenance system. A proper preventive and predictive maintenance of facilities is ensured and, furthermore, the system is able to predict failure and reduce costs. Finally, it is determined that the overall system complies with the initial specifications of the paper and it is fully prepared to carry out test in real blades of wind turbines.

Acknowledgments The work reported herewith has been financially supported by the Spanish Ministerio de Economła y Competitividad, under Research Grant DPI2015-67264, and the FP7 Research project with reference FP-7-Energy-2012-TREN-1:322430.

References

1. Blonquist J, Tanner B, Bugbee B (2009) Evaluation of measurement accuracy and comparison of two new and three traditional net radiometers. Agric For Meteorol 149(10):1709–1721
2. de la Hermosa González RR, Márquez FPG et al (2014) Pattern recognition by wavelet transforms using macro fibre composites transducers. Mech Syst Signal Process 48(1):339–350
3. de la Hermosa González RR, Márquez FPG et al (2015) Maintenance management of wind turbines structures via mfcs and wavelet transforms. Renew Sustain Energy Rev 48:472–482
4. García Márquez FP, García-Pardo IP (2010) Principal component analysis applied to filtered signals for maintenance management. Qual Reliab Eng Int 26(6):523–527
5. Gómez Muñoz CQ, García Márquez FP (2016) A new fault location approach for acoustic emission techniques in wind turbines. Energies 9(1):40
6. Gómez Muñoz CQ, De la Hermosa Gonzalez-Carrato R et al (2014) A novel approach to fault detection and diagnosis on wind turbines. Glob Nest J 16:1029–1037
7. Gómez CQ, Villegas MA et al (2015) Big data and web intelligence for condition monitoring: a case study on wind turbines. Handbook of Research on Trends and Future Directions in Big Data and Web Intelligence; Information Science Reference, IGI Global: Hershey, PA, USA

8. Ibarra-Castanedo C, Bendada A, Maldague X (2011) In infrared vision applications for the nondestructive testing of materials. In: 5th Pan American conference for NDT, Cancun, Mexico
9. Klassen S, Ritchie G et al (2003) Real-time imaging of ground cover: relationships with radiation capture, canopy photosynthesis, and daily growth rate. Digital imaging and spectral techniques: applications to precision agriculture and crop physiology (digitalimaginga):3–14
10. Marquez FPG (2006) An approach to remote condition monitoring systems management. In: Railway Condition Monitoring, 2006. The Institution of Engineering and Technology International Conference on, IET, pp 156–160
11. Márquez FPG, Pedregal DJ, Roberts C (2015) New methods for the condition monitoring of level crossings. Int J Syst Sci 46(5):878–884
12. Márquez FPG, Pérez JMP et al (2016) Identification of critical components of wind turbines using fta over the time. Renew Energy 87:869–883
13. Muñoz CQG, Marquez FPG et al (2015) A new condition monitoring approach for maintenance management in concentrate solar plants. In: Proceedings of the Ninth International Conference on Management Science and Engineering Management, Springer, pp 999–1008
14. Papaelias M, Cheng L et al (2016) Inspection and structural health monitoring techniques for concentrated solar power plants. Renew Energy 85:1178–1191
15. Pliego Marugán A, García Márquez FP, Pinar Pérez JM (2016) Optimal maintenance management of offshore wind farms. Energies 9(1):46

Chapter 2
The Combination of Evolutionary Algorithm Method for Numerical Association Rule Mining Optimization

Imam Tahyudin and Hidetaka Nambo

Abstract The numerical problem of association rule mining is an updated issue. Numerous authors propose some methods to solved it. A number of them are using the optimization approach by Particle Swarm Optimization (PSO). The problem is that the PSO trapped in local optima when searched the best particle in every iteration. Many researchers solved this problem by combining with Cauchy distribution because it is tremendous for searching in a large neighborhood. Hence, that combination will be implemented to accomplish the numerical association rule mining problem for some objective functions such as confidence, comprehensibility, interestingness. Based on the result the multi-objective of PSO for Numerical Association Rule Mining Problem with Cauchy Distribution (PARCD) showed the better result than the method of Multi-objective Particle Swarm Optimization for Association Rule Mining (MOPAR).

Keywords PSO · Cauchy distribution · Numerical association rule mining · Multi-objective functions

2.1 Introduction

Association rule mining is one of methods in data mining which interesting to discuss deeply. This method mines the data that emerge frequently in the same time together. This method evolves increasingly and it is combined by other multidiscipline like machine learning and evolutionary algorithm. For instance, combination ARM with fuzzy concept [1], ARM with PSO [2] and ARM with GA [3].

I. Tahyudin (✉) · H. Nambo
Graduate School of Natural Science and Technology Division of Electrical Engineering and Computer Science, Kanazawa University, Kanazawa, Japan
e-mail: imam@blitz.ec.t.kanazawa-u.ac.jp

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_2

The familiar algorithms which are used in this methods are A priori and FP growth algorithm. Both of them implemented in specific case like A priori algorithm which used for large number database but the FP growth preferred used for small number database [4]. In addition, both of them appropriate used for categorical data type like gender or binary form while if the data is numerical type such as age, weight or length, it there is additional discretization step which transform the data into categorical type. In contrast, this step has many weaknesses like missing many information and need more time to process it [2, 5].

To solve numerical data type in ARM has tried by some researchers. They tried by mono objective just using two parameters which are support and confident. On the other hand, they using multi objectives measurements, not only both parameters but also comprehensibility and interestingness. Moreover, some of them have used pareto optimality for fitness computation while did not use it [4]. One of contribution of this research is combining one of optimization method in numerical ARM, PSO, with Cauchy distribution which was introduced by [6] as the method simple and robust. This combination to prevent the weakness of PSO that premature in searching optimal solution. Hence, this research has aim to bring the hybrid of PSO with Cauchy distribution to solve multi objective numerical ARM optimization by pareto optimality.

The paper is organized as follows: Sect. 2.2 reviews the literature of recent research works; Sect. 2.3 presents the proposed method of combination of PSO and Cauchy distribution for numerical association rule mining optimization (PARCD); Sect. 2.4 gives a discussion and analysis of numerical experiments results for some multi objective problem such as support, confidence, comprehensibility, interestingness, amplitude and coverage; finally, the conclusion and future work are given in Sect. 2.5.

2.2 Literature Review

Nowadays, numerical ARM problem updated to discuss. Many researchers solved this problem in numerous approaches for example by evolutionary algorithm like particle swarm optimization and other machine learning methods like fuzzy and genetic algorithms. In [5] depicts the numerical association rule problem be able to solved by discretization, distribution and optimization. The discretization is done by partitioning and combining, clustering and fuzzy [1, 7]. Then, the optimization is approached by optimized Association rule mining [3], differential evolution [8], Genetic Algorithm (GA) [5, 9, 10] and Particle swarm optimization (PSO) [2, 11, 12]. Whole of them are described in Fig. 2.1.

By those solution, the numerical data can be solved to attain the important information without discretization process [2, 13] and in some method can automatically determine the minimum support and minimum confident based on the optimal threshold without decide by the authors [3, 10].

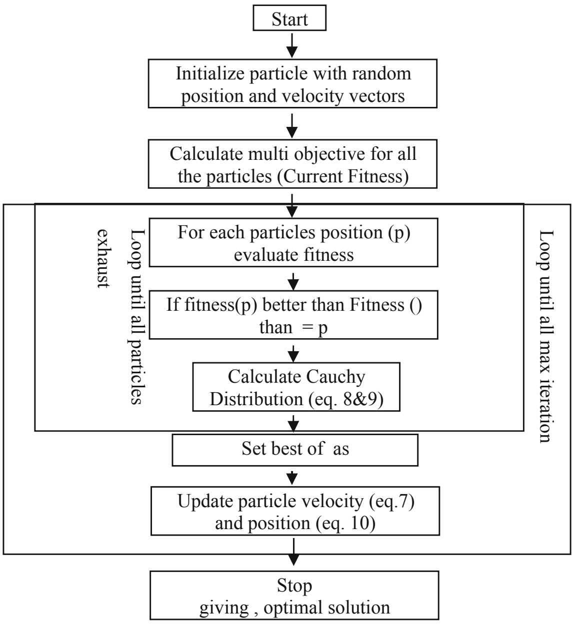


Fig. 2.1 Flowchart of PARCD

According to the latest paper by [2] that the numerical ARM optimization problem has solved by using PSO well. The strengths of PSO are it can define the parameter without specifying upfront the minimum support and confident and also it able to generate best rule independent of length of frequent item set [14]. On the other hand, PSO method has the weakness like the user has to specify the number of best rule and the time of complexity [14] and also it is not robust in large data [6]. So that, it is still potential to be evolved. One of the ways to diminish the weakness is revealed in [6], that the combination of PSO with Cauchy has approved can rise the leverage of result because the mutation process can reach wider and appropriate to a large database. In other research [15] that combination of them have ability to optimize two-stage reentrant flexible flow shop with blocking constrain. In addition this combination can improve the make span solution by average 15, 60 % and then the performance of this combination higher than HGA [15]. Then, this combination have used to optimize the integration of process planning and scheduling (IPPS) and the result shows the effectiveness of the proposed IPPS method and the reactive scheduling method [16]. This hybrid method has developed by Gen et al. to increase the wide search space in mutation process by using Cauchy distribution like revealed in [15, 17], the result shows that the method can enhancing the evolutionary process with the wide search space. Hence, refer to those previous researches, we have novelty to bring this modification method in [15, 17] to be implemented in numerical association rule mining optimization.

2.3 Proposed Method

2.3.1 Objective Design

In this study Authors use some objective parameters which are support, confidence, comprehensibility, and interestingness. The support criterion measures the ratio of transactions in D containing X, or $\sup(X) = |X(t)|/|D|$. The support of the rule $X \rightarrow Y$ is computed using the following equation

$$\text{Support}(X \cup Y) = |X \cup Y|/|D|. \tag{2.1}$$

This support measure is used for determining the confidence criterion. The confidence measures the quality of rule based on the number of transaction of an AR in the whole dataset. The rule which often emerge in every transaction is considered to have a better quality [2].

$$\text{Confidence} = \text{Support}(X \cup Y)/\text{Support}(X). \tag{2.2}$$

Individually, this confidence measure not be guarantee obtaining the appropriate AR. In order to gain the appropriate coverage and reliability, the resulted rule also be comprehensible and interesting. According to a research, the less number of conditions in the antecedent part of a rule would be, the more comprehensible or understandable is that rule [18]. Hence, the comprehensibility can be measured as below

$$\text{Comprehensibility} = \log(1 + |Y|)/\log(1 + |X \cup Y|), \tag{2.3}$$

where $|Y|$ is the number of rule in the consequent the and $|X \cup Y|$ is the total rule in the consequent and antecedent rules.

The interestingness criterion is used for obtaining hidden information by extracting of such surprising rules. This criterion based on support count of both antecedent and consequent part [18]. The equation is shown in Eq. (2.6).

$$\text{Interestingness} = \left[\frac{\text{Support}(X \cup Y)}{\text{Support}(X)}\right] \times \left[\frac{\text{Support}(X \cup Y)}{\text{Support}(Y)}\right] \times \left[1 - \frac{\text{Support}(X \cup Y)}{|D|}\right]. \tag{2.4}$$

The interestingness formula consists of three parts. Firstly, [Support$(X \cup Y)/$ Support(X)], the generation probability of the rule is computed in terms of the antecedent part of the rule. Secondly, [Support$(X \cup Y)/$Support(Y)], the generation probability of the rule is computed in terms of the consequence part of the rule. Finally, in the third part, [$1 -$ Support$(X \cup Y)/|D|$], the section Support$(X \cup Y)/|D|$ shows the probability of generating the rule according to the total records of the dataset ($|D|$). So, its complement, [$1 -$ Support$(X \cup Y)/|D|$], means the probability of not generating the rule. Therefore, a rule with a high value of support count will be considered as a less interesting rule [2].

2.3.2 PSO

Kennedy and Eberhart [12] explained the Swarm Intelligence (SI) that it is an innovative distributed intelligent paradigm for solving optimization problems that originally took its inspiration from the biological examples by swarming, flocking and herding phenomena in vertebrates. In 1995, They found the PSO which incorporates swarming behaviors observed in flocks of birds, schools of fish, or swarms of bees, and even human social behavior.

The main concept of PSO is initialized with a group of random particles (solutions) and then searches for optima by updating generations. During all iterations, each particle is updated by following the two "best" values. The first one is the best solution (fitness) it has achieved so far. This value is called "pBest". The other "best" value that is tracked by the particle swarm optimizer is the best value obtained so far by any particle in the population. This best value is a global best and is called "gBest". After finding the two best values; each particle updates its corresponding velocity and position [12].

Each particle p, at some iteration t, has a position $x(t)$, and a displacement velocity $v(t)$. The personal best (pBest) and global best (gBest) positions are stored in the associated memory. The velocity and position are updated using Eqs. (2.5) and (2.6) respectively [6, 12].

$$v_i^{\text{new}} = \omega v_i^{\text{old}} + c_1 \text{rand}(.)(\text{pBest} - x_i) + c_2 \text{rand}(.)(\text{gBest} - x_i), \quad (2.5)$$

$$x_i^{\text{new}} = x_i^{\text{old}} + v_i^{\text{new}}, \quad (2.6)$$

where ω is the inertia weight; v_i^{old} is particle velocity of the ith particle before updating; v_i new is particle velocity of the ith particle after updating; x_i is the ith, or current particle; i is the particle's number; rand(.) is a random number in the range (0, 1); c_1 is the individual factor; c_2 is the societal factor; pBest is the particle best; gBest is the global best Particles velocities on each dimension are clamped to a maximum velocity $V_{\max}$ [6, 12].

2.3.3 PSO for Numerical Association Rule Mining with Cauchy Dist (PARCD)

Cauchy distribution is used for solving the problem of PSO because of not yield good solution for large scale problems including high dimensional variables. Therefore, make new mutation operation by using the effective particles moving. Kaji in [6, 17] proposed a Cauchy particle swarm optimization for solving multi-modal optimization problem.

PARCD is the proposed method to implement for solving numerical association rule mining problem. This combination generates the best result because the weakness of PSO has solved by using Cauchy distribution so can prevent the trap of local optima in best particle to gain the global best by long jump searching using Cauchy mutation.

$$v_i(t+1) = \omega(t)v_i(t) + c_1\text{rand}(.)(\text{pBest} - x_i(t)) + c_2\text{rand}(.)(\text{gBest} - x_i(t)), \tag{2.7}$$

$$u_i(t+1) = \frac{(v_i(t+1))}{\sqrt{v_{i1}(t+1)^2 + v_{i2}(t+1)^2 + \cdots + v_{iK}(t+1)^2}}, \tag{2.8}$$

$$s_i(t+1) = u_i(t+1) \times \tan\left(\frac{\pi}{2} \times \text{rand}[0, 1)\right), \tag{2.9}$$

$$x_i(t+1) = x_i(t) + s_i(t+1). \tag{2.10}$$

2.3.4 Pseudocode of PARCD

Pseudocode of PSO [17]:

Procedure: Combination of PSO and Cauchy distribution for Numerical ARM Input: PARCD parameters

Output: Multi-objective results

```
Begin
t ← 0
initialize x_i(t) by encoding routine; calculate the multiple objectives for all particles // current fitness
evaluate x_i(t) by decoding routine and keep the best solution;
while (not terminating condition) do
      for each particle x_i in swarm do
          update velocity vi(t + 1) // using (2.7)
          update position x_i(t + 1) //using (2.10)
          calculate u_i(t + 1) and s_i(t + 1) //By Cauchy distribution using (2.8) and (2.9)
          evaluate x_i(t + 1) //using (2.10)
          if f(x_i(t + 1)) < f(pBest(t)) then //pbest(t) : historical best position
            update pBest(t) = x_i(t + 1); //update the best local position
          end;
          gbest(t + 1) = arg min{f(pbestk(t), gbest(t)} //update the global best position
          t ← t + 1;
      end;
      output : the best solution gBest;
end;
```

Table 2.1 Properties of the datasets

Dataset	No. of records	No. of attributes
Quake	2178	4
Basketball	96	5
Body fat	252	15
Pollution	60	16
Bolt	40	8

Table 2.2 The parameter setup

Parameter	Population size	External repository size	Number of iteration	C_1 and C_2	W	limit	xRank
Average	40	100	2000	2	0.63	3.83	13.33

2.4 Experiments and Discussion

2.4.1 Experimental Setup

This research uses benchmark datasets from Bilkent University Function Approximation Repository. There are five data set which are used, Quake, Basketball, Body fat, pollution and Bolt (Table 2.1). This experiment is conducted on 2.7 GHz Intel Core i5, 8 GB main memory, running by Windows 7 and to process the algorithms by using Matlab software.

Firstly, setting up the parameter of some values in the proposed algorithm such as parameter, population size, external repository size, number of iteration, the value of c_1 and c_2, ω, velocity limit and xRank. They are average, 40, 100, 2000, 2, 0.63, 3.83, and 13.33 respectively. This parameter referred to the previous research by [2] (Table 2.2).

2.4.2 Experiments

Basically, the association rule analysis contains two steps, firstly to determine the frequent item set including the antecedent or consequent from each attributes. Secondly, to implement the proposed algorithm. In this research uses the development method of multi-objective particle swarm optimization of numerical association Rule (MOPAR) which is combined with Cauchy distribution (mutation). We call as PARCD (Particle swarm optimization of numerical association rule with Cauchy distribution).

The Table 2.3 shows about the comparison of support value between PARCD and MOPAR method. Generally, the support percentage of PARCD method is better

Table 2.3 The comparison of support value

Dataset	Support (%)	
	PARCD	MOPAR
Quake	22.97	46.26
Basket ball	61.04	32.13
Body fat	73.94	10.1
Bolt	250.84	107.29
Pollution	60.45	52.14

Table 2.4 The Comparison of number of values and confidence values

Dataset	Number of rules		Confidence (%)	
	PARCD	MOPAR	PARCD	MOPAR
Quake	51	57	86.73 ± 25.88	82.31 ± 28.91
Basket ball	78	84	92.69 ± 17.87	92.67 ± 16.65
Body fat	32	29	81.26 ± 30.67	43.59 ± 61.15
Bolt	42	39	96.88 ± 9.49	88.91 ± 9.49
Pollution	12	2	34.96 ± 43.91	23.02 ± 40.04

than MOPAR method. Only one dataset that the value is opposite unlike the other datasets; Quake, which is the value in PARCD method is almost half value from MOPAR methods. The considerably highest gap percentage support value is Bolt dataset which is just over by 150 %. On the other hand, the lowest one is Body fat dataset which is approximately one per seven from the percentage its result by PARCD. In addition, the percentage of Basket ball by the proposed method doubled from the value by MOPAR. Interestingly, the value of pollution dataset is nearly similar just about of 7 %.

This result makes the argue that the combination of PSO with Cauchy distribution can reach the large space to search the optimal value. This result also affects to the value of rule numbers and the confidence percentage which are generated in Table 2.4.

This table reveals the differentiation both of PARCD and MOPAR method of number of rules and confidence value. According to number of rules, there are three datasets which are the PARCD method is better than MOPAR method. They are body fat, bolt and pollution. However, it clearly shows in confidence value that all the value in PARCD method is higher than the MOPAR method. Although, the highest value of rules number, basket ball, is higher at 6 from the opponent of MOPAR, the confidence value is almost the same even little bit higher. Interestingly, the lowest value of rule number also by MOPAR method which is pollution (about one sixths from the PARCD method). Furthermore, the highest percentage of confidence is Bolt which is at 96,88 %. In addition, the percentage of body fat dataset by PARCD method is two times higher than its value in MOPAR method and then for quake and pollution datasets are higher by about 4 and 10 % respectively.

Table 2.5 The comparison of comprehensibility value

Dataset	Comprehensibility (%)	
	PARCD	MOPAR
Quake	785.2 ± 37.72	786.14 ± 419.67
Basket ball	545.80 ± 167.74	424.65 ± 192.63
Body fat	333.49 ± 218.95	204.87 ± 235.46
Bolt	231.08 ± 168.35	271.25 ± 168.35
Pollution	110.63 ± 165.76	65.82 ± 130.49

Table 2.6 The comparison of interestingness value

Dataset	Interestingness (%)	
	PARCD	MOPAR
Quake	2.34 ± 9.30	4.67 ± 11.40
Basket ball	6.56 ± 21.16	4.99 ± 5.18
Body fat	10.61 ± 21.03	21.71 ± 9.30
Bolt	43.43 ± 39.68	23.70 ± 39.68
Pollution	9.51 ± 18.61	10.23 ± 27.88

The confidence value contains the average of iteration and the standard deviation is to show that the final value is acceptable from fluctuation in some iteration and the stable behavior in every run [2]. It also done in comprehensibility value (Table 2.5), interestingness value (Table 2.6).

This Table 2.5 obviously shows that three kinds of dataset by PARCD method have the higher value than by MOPAR methods. They are basket ball, body fat and pollution. The highest value of two methods is nearly same, it is Quake dataset (about 785). In contras the lowest one is pollution dataset which is at 110.63 and 65.82 % from PARCD and MOPAR method respectively. The basket ball and body fat dataset by PARCD method are higher about 100 % than their value in MOPAR method. Moreover, the bolt dataset is little bit less than approximately unlike the other datasets.

The interestingness table attend balance value. It means there are two datasets in every method has the higher value and there is one data set which the approximately similar. The datasets by PARCD which are higher than MOPAR method are basket ball and bolt (6.56 and 43.43 %). Where the value of bolt is two time higher than opponent. On the other hand, the two remain datasets which are quake and body fat by MOPAR method are double than their value in PARCD. Then, the last dataset which is almost the same is pollution. It is about 10 % (Table 2.7).

Table 2.7 The comparison of coverage value

Dataset	Coverage (%)	
	PARCD	MOPAR
Quake	71.32	59.43
Basket ball	82.55	87.5
Body fat	99.48	6.28
Bolt	95.37	89
Pollution	91.58	89

The coverage table depicts that almost the datasets by PARCD method higher than MOPAR method which are the average over 90 % except quake dataset. The significantly highest gap value is body fat by 93 % and the lowest ones are pollution (just under 2 %). Then the remains are basket ball, pollution and quake the gaps are amount 5, 6 and 12 % respectively. Interestingly, the percentage of coverage of bolt and pollution by MOPAR method has the same value which are 89 %.

This table strongly give reason that the PARCD method can reach wider than the MOPAR method to searching the optimal value. This is because the proposed method, PARCD contain combination between PSO and Cauchy distribution which empirically prevent the PSO traps in local optima. It also makes additional evidence that this combination robust to solve some problems in different field including the numerical association rule mining optimization problem.

2.5 Conclusions

Based on this study, the weakness of PSO for solving numerical association rule mining problem can be solved by combining with Cauchy distribution. The problem of PSO that premature in minimum optima for searching in large dataset can be handled well in multi-objective function. The experiment by the method of PARCD showed obviously that in every multi-objective function such as confidence, comprehensibility and interestingness give the result better than previous method (MOPAR) which is only using PSO for solving multi-objective in numerical association rule mining problem.

For the future, because of the problem of numerical association rule mining is still be improved so it will be better to following the research for instance it combining with other methods like genetic algorithm or fuzzy algorithm.

Acknowledgments This research supported by various parties. We would like to thank for scholarship program from Kanazawa University, Japan and Ministry of Research, Technology and Higher Education (KEMENRISTEKDIKTI) and also STMIK AMIKOM Purwokerto, Indonesia. In addition, we thank for anonymous reviewers who gave input and correction for improving this research.

References

1. Arotaritei D, Negoita MG (2003) An optimization of data mining algorithms used in fuzzy association rules. In: Knowledge-based intelligent information and engineering systems. Springer, pp 980–985
2. Beiranvand V, Mobasher-Kashani M, Bakar AA (2014) Multi-objective PSO algorithm for mining numerical association rules without a priori discretization. Expert Syst Appl 41(9):4259–4273
3. Yan X, Zhang C, Zhang S (2009) Genetic algorithm-based strategy for identifying association rules without specifying actual minimum support. Expert Syst Appl 36(2):3066–3076
4. Almasi M, Abadeh MS (2015) Rare-pears: a new multi objective evolutionary algorithm to mine rare and non-redundant quantitative association rules. Knowl Based Syst 89:366–384
5. Minaei-Bidgoli B, Barmaki R, Nasiri M (2013) Mining numerical association rules via multi-objective genetic algorithms. Inf Sci 233:15–24
6. Li C, Liu Y et al (2007) A fast particle swarm optimization algorithm with cauchy mutation and natural selection strategy. In: Advances in computation and intelligence. Springer, pp 334–343
7. Alhajj R, Kaya M (2008) Multi-objective genetic algorithms based automated clustering for fuzzy association rules mining. J Intell Inf Syst 31(3):243–264
8. Alatas B, Akin E, Karci A (2008) Modenar: multi-objective differential evolution algorithm for mining numeric association rules. Appl Soft Comput 8(1):646–656
9. Kaya M (2006) Multi-objective genetic algorithm based approaches for mining optimized fuzzy association rules. Soft Comput 10(7):578–586
10. Qodmanan HR, Nasiri M, Minaei-Bidgoli B (2011) Multi objective association rule mining with genetic algorithm without specifying minimum support and minimum confidence. Expert Syst Appl 38(1):288–298
11. Alatas B, Akin E (2008) Rough particle swarm optimization and its applications in data mining. Soft Comput 12(12):1205–1218
12. Indira K, Kanmani S (2015) Association rule mining through adaptive parameter control in particle swarm optimization. Comput Stat 30(1):251–277
13. Álvarez VP, Vázquez JM (2012) An evolutionary algorithm to discover quantitative association rules from huge databases without the need for an a priori discretization. Expert Syst Appl 39(1):585–593
14. Sarath K, Ravi V (2013) Association rule mining using binary particle swarm optimization. Eng Appl Artif Intell 26(8):1832–1840
15. Sangsawang C, Sethanan K et al (2015) Metaheuristics optimization approaches for two-stage reentrant flexible flow shop with blocking constraint. Expert Syst Appl 42(5):2395–2410
16. Yu M, Zhang Y et al (2015) Integration of process planning and scheduling using a hybrid GA/PSO algorithm. Int J Adv Manuf Technol 78(1–4):583–592
17. Gen M, Lin L, Owada H (2015) Hybrid evolutionary algorithms and data mining: case studies of clustering. In: Proceedings of social plant engineering Japan 2015 autumn conference
18. Ghosh A, Nath B (2004) Multi-objective rule mining using genetic algorithms. Inf Sci 163(1):123–133

Chapter 3
On Interactive Learning and Mutual Trust Within the Innovation Network

Lin Luo, Xin Gu, Qifeng Wei and Huashan Li

Abstract Interactive learning is an important source of competitive advantage. Consisting of innovative enterprises, universities, research institutes, etc., innovation network has become an important carrier of interactive learning. As a binder of relationships among innovation organizations, the level of trust determines the operational performance of the innovation network. This paper discusses the interactive learning and evolution of mutual trust within the innovation network, as well as the "symbiotic" interaction between them, which has important influence on the knowledge transfer efficiency and operational performance of the innovation network. Moreover, game theory is applied to analyze the building process of mutual trust under different conditions, and then the conditional inequalities needed to be met are deduced in this paper. Finally, this paper proposes three managerial enlightenments.

Keywords Innovation network · Interactive learning · Trust · Evolution

L. Luo (✉) · X. Gu
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: candyall@163.com

L. Luo
Sichuan Technical Exchange Center, Chengdu 610041, People's Republic of China

Q. Wei
Business School, Chengdu University of Technology, Chengdu 610059, People's Republic of China

H. Li
Faculty of Business and Economics, The University of Melbourne, Melbourne 3010, Australia

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_3

3.1 Introduction

Nowadays, with the aim of obtaining, integrating, and creating new technologies or new knowledge, many enterprises, universities, research institutes, government agencies and some other intermediary service organizations are building up innovation networks through inter-organizational contract or equity relationships, which has already become an important way to develop [1, 2]. The professional knowledge the organizations within the innovation network are holding are always dispersed or incomplete, in order to acquire network cooperative effect, different organizations implement a certain learning mechanism to get these dispersed heterogeneous knowledge, which is called interactive learning [3]. Interactive learning is the basic activity and function of innovation network, and also a key way to facilitate inter-organizational knowledge flow, to finally achieve knowledge integration and innovation [4]. Currently, there are many studies showing that there is a direct link between interactive learning and innovation, Fribsch and Franke [5] even considered innovation as an interactive learning process. Interactive learning is also considered to have significant positive impact on the creation of tacit knowledge [6]. Along with the interactive learning and inter-organizational knowledge flow, the mutual trust among organizations within the innovation network is forming and evolving to develop [7].

When the heterogeneous organizations within the innovation network cannot reduce uncertainty by rule or routines, the trust, has become the primary means for network members to reduce the complexity [8]. Most of the time, in the inter-organizational cooperation, mutual trust is treated as the critical factor for the success of partnerships [9]. Also, Intensity and nature of trust is closely related to the knowledge transfer level of innovation network, as Zhou et al. argued [10], trust in network played an intermediary role in the influence of network centrality on the effectiveness of the knowledge transfer.

So is there any correlation between interactive learning and mutual trust? What's the interaction like? We cannot find sufficient evidences from existing studies. Based on the context of innovation network, this paper discusses the evolution of innovative interactive learning and trust in the network, and the interaction between them.

3.2 Interactive Learning Within the Innovation Network

As a specific type of network, innovation network has the general learning characteristics of network organizations, new technology and new knowledge are its main content for production and use. Based on literature review, Li and Qiu [11] stated that network organization has five basic characteristics including node activity and hierarchy, interdependence, linking diversity, continuous interaction, intermediate, and five derived characteristics including embedded, complexity, flexibility, diversity, cooperation. On the one hand, these learning characteristics of the network organization determine that it's an appropriate way for interactive learning; on the other hand, as the basic operating mechanism of network organization, organizational learning plays an irreplaceable role in the formation and evolution of the network organization.

Innovation network is an important media of interactive learning for innovation subjects, to achieve the complementary effect. By facilitating knowledge share and knowledge creation via members' interaction, inter-organizational interactive learning would be further affected to have impacts on the network performance. The learning content among subjects includes many aspects as obtaining, sharing, integration and application of both tacit knowledge and explicit knowledge, knowledge application is the result of organizational learning, which is also the knowledge integration to apply to the new development environment [12]. What T odtling and Kauffman [13] argued is, interactive learning among organizations is integrated in the process of their interaction. The interactive learning among organizations, contributes to the knowledge production, diffusion and application. Innovation network, with the enterprises as its core part, is embedded in a particular social network, the network structure, the strength of the relationship among organizations, and social capital, all have important impacts on the interactive learning within the innovation network [14].

3.2.1 The Types and Process of Interactive Learning Within the Innovation Network

Interactive learning among organizations, different from the traditional organizational learning, emphasizes the cross-organizational characteristics, and with this specific "learning environment", interactive learning among organizations is performed as the "network learning", which is defined by Dyer as the knowledge development and acquisition in a specific network environment, or the knowledge acquired from the knowledge storage mechanism of all levels and the knowledge flow of compilation network [15]. Along with the knowledge flow process among organizations, interactive learning consists of knowledge share, knowledge acquisition, knowledge application, knowledge creation and knowledge feedback stages. In this process, knowledge stock, learning capability and competitiveness are gradually raised.

Innovative enterprises are the core of innovation network, through vertical or horizontal contact ways, they construct multiple contacts with other enterprises, research institutes, universities, and intermediary service organizations. And therefore, four main interactive learning channels are produced, such as vertical interactive learning between enterprise and its supplier or customer, horizontal interactive learning between enterprise and enterprise, interactive between enterprise and universities or research institutes, interactive learning between enterprise and agency or government departments. Four types of learning constitute a basis for the operation of innovation network, which guarantee the smooth knowledge flows. Seeing from the link types, two types of learning are embedded in the four learning channels, namely

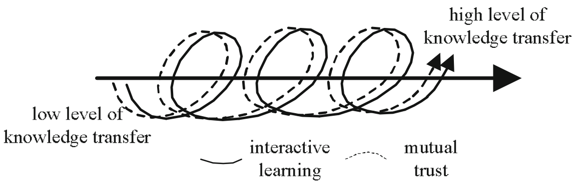


Fig. 3.1 The interaction between interactive learning and mutual trust

the formal learning at organizational level and informal leaning at individual level. Although to some extent, the learning at organizational level will eventually be implemented to the individual level, but the learning at organizational level are maintained through economic relations among organizations, namely, it's the technology, knowledge transfer, and interactive learning maintained by contract or equity, for instance, formal learning occupies a dominant position in the research collaboration in joint lab; informal learning is coupled through interpersonal network, and then produces knowledge flow, which is mainly expressed as the face to face communication of personnel who are belonging to different organizations in non-market trading activities. But both levels are not isolated, and two-way interactive correlation exists. According to Nonaka's SECI model, in this process, knowledge transformation within the innovation network presents an upward spiral developing pattern, along with the deepening of knowledge transfer and diffusion, the degree of mutual trust all has a positive change, and thus affects the robustness of the innovation network, see Fig. 3.1.

3.2.2 Characteristics of Interactive Learning Within the Innovation Network

Learning is the endogenous characteristics of network [11]. On the one hand, the learning characteristics mean that network is suitable for the interactive learning among organizations; on the other hand, organizational learning and knowledge management are important constituents of the operation mechanism of network, which play an important role in the formation and evolution of network. Distinguished from the linear and adaptive learning of other general organizations such as enterprises, the interactive learning within the innovation network, essentially, emphasizes its creativity, and its learning process is dynamic and interactive. The levels which interactive learning evolves, includes individual, group, organization and inter-organizational, namely, learning is a process that expanding from individual to group, and from group to a whole organization, and eventually break through the organizational boundary to the whole innovation network. In addition, innovation network platform provides a knowledge platform which is knowledge-intensive and easy to do knowledge share and spillovers for the subjects within different networks. Interactive learning within innovation network shows a higher enrichment of knowledge, which is very special.

In the early stage of innovation network formation, due to the geographical proximity, there're many chances for enterprises to communicate and generate economic transactions with other innovation organizations, by increasing learning efficiency and frequency, the collaboration and trust are enhanced. During this process, social capital plays an intermediary effect in the interactive learning among organizations. And trust is the core dimension of social capital, the social capital in innovation network promotes the formation and evolution of trust among organizations, so as to provide a guarantee for the efficient knowledge transfer and diffusion of tacit knowledge. Since compared to explicit knowledge, tacit knowledge is the source of competitive advantage, and thus in innovation network, various organizations have attached great importance to training and maintaining the trust relationships.

3.3 Mutual Trust Within the Innovation Network

3.3.1 Evolution of Mutual Trust Within the Innovation Network

Although scholars with different cultural contexts haven't reached a consensus on the definition of the concept of trust, when some of them are using "trust", often means different things [16], yet subtly emphasizes that trust is a dependency relationship between the trustor and trustee, particularly the expectation to trustee in uncertainty. Therefore, in terms of the trust in innovation network, it must contain the affirmation on verbal behaviors of other organizations, and all the network subjects will try to implement the self-interested desired behaviors, rather than to use other's weakness to serve a selfish purpose. This trust is based on the full agreement on the ability and expected behaviors of others. But it is inherently uncertain and risky, the parties who trust each other should rely on each other too, especially in the interactive learning among the organizations in innovation network. Dirks and Ferrin [17] suggested that the role of trust can be divided into main effect and moderating effect. From the degree of trust, as Barney and Hansen pointed out, between organizations, there're three levels of mutual trust: low degree, moderate degree, high degree [18]. Low degree of trust means that there is a limited possibility of opportunism, but a low degree of trust does not necessarily lead to mutual deception among innovation network members. Prior to this, members still showed confidence in each other, because they believe in themselves that there are no obvious weaknesses, which will not be used as a weapon to damage their own interests by the other party. Moderate degree of trust can be called "Governance Trust". When the cooperation is vulnerable, and innovative network members want to protect their interests through various governance mechanisms, the moderate trust appears. High degree of trust is also called "absolute trust". When the partnership is facing a huge threat vulnerability, regardless of whether there is social or economic governance mechanisms, a high degree of mutual trust will appear among members.

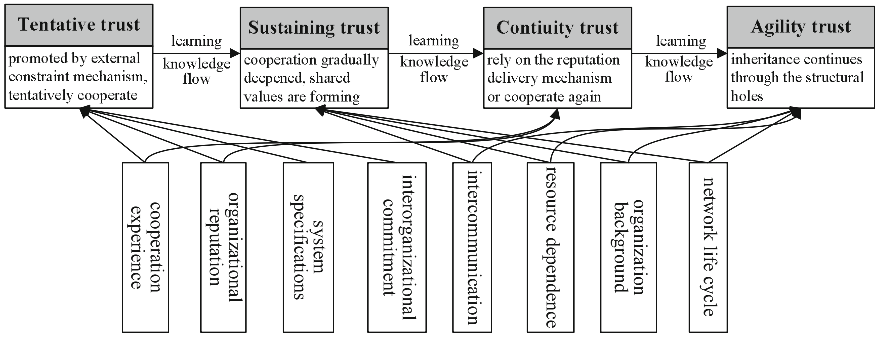


Fig. 3.2 Interactive learning and knowledge transformation within innovation network

Generally, at the beginning of the partnership, interactive learning is established on the credibility trust which is built on the rules, willingness of commitment completion, and the ability, such as system-based trust, computational trust, and cognition-based trust. As Gulati noted [19], there're two ways of that the cooperation network may influence the inter-organizational trust, one is the trust based on knowledge, the other one is the trust based on calculated. With the level of understanding deepening, members think of each other "kind", "effectiveness" of interactive learning comes from the emotional trust generated from the repeated interaction, and they form the understanding trust, emotional trust, identity-based trust, which are all affected by different factors in the network. Based on the analysis above, and refer to the model presented by Wang [7], a conceptual model of inter-organizational trust evolution model within innovation network is presented in this paper (Fig. 3.2).

3.3.2 Game Analysis on the Establishing Process of Mutual Trust

In the innovation network, whether the members cooperate or not, and whether to trust or not, are both game behaviors. And whether the trust could be established among organizations, is the selection result of "mutual trust" or "opportunism", which is a game equilibrium. Establishment and development of trust is associated with the cycle of innovation network knowledge activities, the basic unit of which is the knowledge flow process. What Nash equilibrium states is that when the policy combination consisted of the optimal strategies of all participants reaches the Nash equilibrium, no single participant has a positive selection of other strategies to break the equilibrium, which means Nash equilibrium has the stability. Before constructing the game model, there're following assumptions:

(1) Complete information and economic man hypothesis: suppose the vertexes in innovation network can fully grasp the information, and they're perfectly rational

"economic man", the vertex can accurately calculate the costs and benefits of choice for future strategy, with the objective of pursuing the maximum interests.

(2) Participation strategy space hypothesis: when the vertexes are involved in knowledge activities, there are two strategies choices: the first is cooperative/trust strategy, which means believe in partners, participate in knowledge activities in innovation network to enhance the overall knowledge value and the knowledge stock; the second is uncooperative/distrust strategy, which means break promises to partners, and take opportunistic behavior (adverse selection or moral hazard), harm partner's interests, to maximize their own interests.

(3) Punishment strategy hypothesis: when one party takes opportunistic behavior, the other party will be "tit for tat", in the next phase or later on, he will choose uncooperative/distrust strategy to punish, which is called trigger strategy; at some stage in the game, once anyone chooses opportunism, the other party will always choose opportunism. Assuming there're two vertexes A and B in the innovation network, the payoff matrix of mutual trust building is listed in Table 3.1.

Here we have:

$$P_1 = R_1 + R_1\delta + R_1\delta^2 + \cdots + R_1\delta^{S-1} = \frac{R_1(1-\delta^S)}{1-\delta}, \tag{3.1}$$

$$P_2 = R_2 + R_4 + R_4\delta + \cdots + R_4\delta^{S-2} = R_2 - R_4 + \frac{R_4(1-\delta^S)}{1-\delta}, \tag{3.2}$$

$$P_3 = R_3 + R_4 + R_4\delta + \cdots + R_4\delta^{S-2} = R_3 - R_4 + \frac{R_4(1-\delta^S)}{1-\delta}, \tag{3.3}$$

$$P_4 = R_4 + R_4\delta + \cdots + R_4\delta^{S-1} = \frac{R_4(1-\delta^S)}{1-\delta}. \tag{3.4}$$

In the formulas, δ is the prior probability of the next game, S is the number of the game. R is the income of one single game, P means the income of S repeated game. In the cooperation, there're three possible values of S: once, finite N or infinite, representing the single game, finitely repeated game and infinitely repeated game.
(1) Single Game Here, S = 1, and the game payoff matrix is listed as Table 3.2, each segment value means the earning of every combination of corresponding behaviors.

We could see that, whether the trust behavior occurs or not, depends on the comparison of the benefits of trust and distrust. When the trust income is greater than distrust earnings, in accordance with the principle of own benefit maximization, cooperative/trust strategy becomes the optimal choice. Therefore, rules and norms,

Table 3.1 The game payoff matrix of mutual trust building among network organizations

		Vertex B	
		Cooperative/Trust	Uncooperative/Distrust
Vertex A	Cooperative/Trust	P1A, P1B	P2A, P3B
	Uncooperative/Distrust	P3A, P2B	P4A, P4B

Table 3.2 Single game payoff matrix of the mutual trust's establishment among organizations

		Vertex B	
		Cooperative/Trust	Uncooperative/Distrust
Vertex A	Cooperative/Trust	R1A, R1B	R2A, R3B
	Uncooperative/Distrust	R3A, R2B	R4A, R4B

mortgages, contracts, and reputation transmission are needed to protect the mutual trust.

(2) Repeated Games

If the partnership is expected to continue, the partner may calculate whether the current period income of default (distrust) is greater than that of continued cooperation or not. Continued cooperation is reflected as the repeated game, in which every game is called a "stage game". The payoff matrix is seen as Table 3.1.

① Finitely repeated games

In this case, the value of S is finite N, a natural exact value. According to the theorem of finitely repeated games: if there's only one Nash equilibrium in stage game, there is only one perfect Nash equilibrium in finitely repeated games. When N is determined, all parties know the exact number of bilateral cooperation in the game, according to backward induction, the last Nash equilibrium must be (uncooperative/distrust, uncooperative/distrust), penultimate actually become backstepping the last time, also it must be a balanced result (uncooperative/distrust, uncooperative/distrust), and so on. As can be seen, finitely repeated game is the same as single game, the results are obtained (uncooperative/distrust, uncooperative/distrust) Nash equilibrium, the earning is (P_{4A}, P_{4B}), which is still the Pareto low effect equilibrium of collective irrational.

② Infinitely repeated games

In this case, the value of S is infinite. Infinitely repeated can break through the prisoner's dilemma, because in the process of infinitely repeated games, the opportunist will face the threat of losing the earnings of long-term strategies in the future through penalty. Assuming in the first game, A chooses cooperative/trust strategy, B chooses the same, then the earning of A is R_{1A}, B is R_{1B}, in the following S-1 stage games, both choose cooperative/trust strategy, the earning of each stage is R_{1A}, both the earnings of A and B are the sum of earnings of S stages P_1, the calculation is as formula (3.1).

Suppose A chooses cooperative/trust strategy in the first game, while B chooses uncooperative/distrust strategy, namely, he takes opportunistic behavior, then the earnings to A is R_{2A}, earnings to B is R_{3B}. As both will co-faced opportunistic and use "trigger strategy" and therefore, in the subsequent second stage game S-1, vertex A and B both will choose opportunism uncooperative/distrust, earnings at each stage are R_4. The earning of A at the first game is R_{2A} and P2A at the following S-1 stages, similarly, earning of B is P_{3B}. According to the symmetry relations of the game, for infinitely repeated games, if one party chooses trust, another party chooses distrust in the first cooperation: the earning of the vertex who chooses cooperative/trust strategy is P_2, see formula (3.3); the earning of the vertex who chooses uncooperative/distrust strategy is P_3. Similarly, suppose that both A and B choose upcooperative/distrust, their earnings would be $(R_{4A},\ R_{4B})$, in the following S-1 games, both A and B will choose uncooperative/distrust strategy, earnings at each stage is R_4, earnings of two vertexes are the sum of expected earnings of S-times stage games P_4, see formula (3.3).

In infinitely repeated games, if both two vertexes chooses cooperative/trust strategy in the first game, and the strategy will be used in subsequent stages, then the game earning is P_1; If both two vertexes choose uncooperative/distrust strategy in the first game, as the strategy continues, the game earning is P_4; If one party choose cooperative/trust, while the other chooses uncooperative/distrust, because of the effect that the trigger strategy on decision-making, in the following stages, both will take uncooperative/distrust strategy, the one who takes cooperative/trust strategy will gain the earning of P2, the one takes uncooperative/distrust will get P3. Regardless of what engagement strategies, cooperative cost exists, assuming the opportunistic behavior costs of cooperative/trust strategy and uncooperative/distrust are Ct and Co respectively. Since $R_3 > R_1 > R_4 > R_2$, according to formula (3.1)–(3.4), what can be inferred is $P_1 > P_4 > P_2$ and $P_3 > P_4 > P_2$. According to the economic man hypothesis, the target of network vertexes is to maximize their own earnings, so in order to promote members to choose cooperative/trust strategy, the condition should be met: $P_1 - C_t > P_3 - C_o$, namely,

$$\frac{R_1(1-\delta^S)}{1-\delta} - C_t R_3 - R_4 + \frac{R_4(1-\delta^S)}{1-\delta} - C_0. \tag{3.5}$$

When this condition is satisfied, indicating in infinitely repeated games, the income that both opted for cooperative/trust strategy will be greater than the income from opportunistic behaviors, mutual trust become the dominant strategy in the transaction and then mutual trust can be established. There are two solutions to satisfy formula (3.5): First, make it inequality by increasing the cost of opportunistic behavior; Second, increase future earnings through continued cooperation, and maintain long-term cooperative relations, to reduce costs to make it inequality.

3.4 The Interaction of Interactive Learning and Trust Evolution Within Innovation Network

Trust in network will not come out of nowhere, but it takes time to develop and act, interactive learning is such a “trust cultivation” behavioral process. With the change of innovation network life-cycle, mutual trust among organizations is gradually built, transferred and continued, which also promotes the formation of relational network, and imbedding in the innovation network. In a true alliance, the open communication

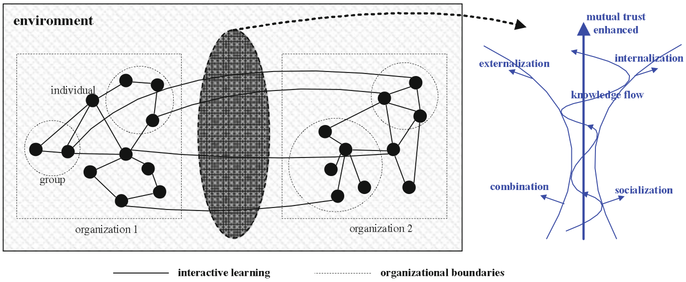


Fig. 3.3 Interactive learning and knowledge transformation within innovation network

among organizations is a necessary condition to build trust relationships [20], based on this, when resources of members are more transparent and behavior extent is less uncertain, the level of trust "floats" high [21]. From the perspective of social relations, trust always occurs in social interaction of transaction [22], as can be seen, interactive learning has a higher explanatory power in the internal aspects of the trust evolution of innovation network.

In addition, according to the theory of institutional economics, from three aspects the trust within innovation network optimizes the interactive learning process [10]. First, the trust effectively save the monitoring costs, as trust means to comply with contracts on the network to ensure the efficiency of knowledge transfer between organizations, and reduce the friction between each other, as well as the unnecessary consultations and negotiations. Second, trust will help to enhance the level of private investment of organization, since private investment will produce appropriable quasi rents, some members may steal the quasi rents owing to the bargaining capacity down after the funder makes the specific investment [23]. Thus, only based on mutual trust, will the members be dedicated in specific investment. Besides, if the communication channels of innovation network are open, any opportunistic transactions will be full disclosure to members, the implementation costs of opportunistic behavior is expelled from the relations network, losing all the future. Therefore, the trust mechanism is eventually evolved into trust self-regulatory mechanism of "social implementation", thus psychological prevention to opportunistic behaviors is eliminated, to promote knowledge sharing and knowledge creation. We argue that, there's a "symbiotic" effect between interactive learning and mutual trust, which has significant influence on the knowledge transfer efficiency and final operational performance (Fig. 3.3).

3.5 Conclusions and Managerial Enlightenments

Seeing from the forming motivation, interactive learning leads to the formation of the network, at the same time, innovation network also provides a knowledge trading platform and place for the interactive learning among organizations. Mutual trust is the key factor in successful partnership of innovation network, in the developing process; the trust relationship evolves along with the logic of "tentative trust", "sustaining trust", "continuity trust" and "agility trust". For practitioners, build and maintain a high level of inter-organizational trust relationships, especially the continuity trust, is the precondition to guarantee high efficiency of knowledge transfer knowledge sharing. Combined with game theory and scenario analysis, the mutual trust should be facilitated by ever-growing earnings and higher costs of opportunistic behaviors. Interactive learning evolves along with the inter-organizational knowledge flow, in this process, there's a "symbiotic" effect between interactive learning and mutual trust, by symbiosis, the efficiency of knowledge transfer and diffusion is improved, so as to enhance the network performance.

According to the accompanying feature analysis of interactive learning and trust evolution, we summarize some managerial enlightenment for innovation network:

(1) In the context of open innovation, for sake of gaining competitive advantage, achieving economies of scale and economies of scope, and share both risks and benefits with partners, to achieve stable and rapid development, it is an important way for enterprises to build or join innovation networks nowadays. Enterprises and other organizations should update their developing ideas, change from organization internally to inter-organizational interactive learning, and establish a continuity trust-based relationship and strategic development alliance, to achieve new development.

(2) Foster the inter-organizational social capital within innovation network, to enhance the network trust. Social capital based on network trust, can effectively eliminate the defensive psychology to the opportunistic behaviors, so as to reduce transaction costs of interactive learning. Organization within innovation network should increase the specific assets investment of cooperative innovation on the one hand, to improve the transposition and exit costs of opportunistic behaviors, use irrevocable investments to lock the parties; on the other hand, open communication should be implemented, to improve resources transparency to enhance the level of knowledge sharing.

(3) The quality of inter-organizational trust relationship within innovation network influences the quality, viability, and performance of relationship. It is also influenced by many factors, such as cooperative experience, organizational reputation, network system and other cultural norms, in different developing stages, managers need to control the main factors, actively intervene in the inter-organizational learning efficiency, improve the trust relationship, to guarantee innovation network run successfully.

Acknowledgments This work is supported by the National Natural Science Foundation of China (71571126), Western Project of National Social Sciences Fund (12XGL003), Innovation Team Project "Knowledge Chain Management" (13TD0040) and General Project of Humanities and Social Sciences (12SB342) of Education Department of Sichuan Province.

References

1. Herstad SJ, Aslesen HW, Ebersberger B (2014) On industrial knowledge bases, commercial opportunities and global innovation network linkages. Res Policy 43(3):495–504
2. Howard M, Steensma HK et al (2015) Learning to collaborate through collaboration: How allying with expert firms influences collaborative innovation within novice firms. Strateg Manag J. doi:10.1002/smj.2424
3. Lundvall BÅ (2010) National systems of innovation: toward a theory of innovation and interactive learning, vol 2. Anthem Press, London
4. Liu CC, Wang KC (2015) U.S. Patent No. 20,150,286,958. Washington, DC: U.S. Patent and Trademark Office
5. Fritsch M, Franke G (2004) Innovation, regional knowledge spillovers and r&d cooperation. Res Policy 33(2):245–255
6. Lan W, Zhangliu W (2012) Research on interactive learning, knowledge sharing andcollective innovation in smes cluster. Int J Innov Manag Technol 3(1):24
7. Wang T, Gu X (2011) Analysis on the establishing process of mutual trust among knowledge network members. J Intell 4(30):102–106
8. Luhman N (1979) Trust and power: two works by Niklas Luhmann. Wiley, Chichester
9. Ring PS, Van de Ven AH (1994) Developmental processes of cooperative interorganizational relationships. Acad Manag Rev 19(1):90–118
10. Zhou M, Zhao XP, Si X (2009) An empirical study of relation between intra-team networks centrality, networks quality and knowledge transfer success. Stud Sci Sci 9:017
11. Li W, Qiu S (2007) Characteristics of the network organizations and their effects on the boost of organizational learning. Sci Res Manag 6(28):175–181
12. DiBella AJ, Nevis EC, Gould JM (1996) Understanding organizational learning capability. J Manag Stud 33(3):361–379
13. Tödtling F, Kaufmann A (2002) Smes in regional innovation systems and the role of innovation support-the case of upper Austria. J Technol Transf 27(1):15–26
14. Wu S (2010) Inter-organizational technology learning in knowledge chain: the analysis based on social network and social capital. Libr Inf Serv 14(54):92–96
15. Dyer JH (1996) Specialized supplier networks as a source of competitive advantage: evidence from the auto industry. Strateg Manag J 17(4):271–291
16. Sitkin SB, Roth NL (1993) Explaining the limited effectiveness of legalistic "remedies" for trust/distrust. Organ Sci 4(3):367–392
17. Dirks KT, Ferrin DL (2001) The role of trust in organizational settings. Organ Sci 12(4):450–467
18. Barney JB, Hansen MH (1994) Trustworthiness as a source of competitive advantage. Strateg Manag J 15(S1):175–190
19. Gulati R (1998) Alliances and networks. Strateg Manag J 4(19):293–317
20. Inkpen AC, Tsang EW (2005) Social capital, networks, and knowledge transfer. Acad Manag Rev 30(1):146–165
21. Dyer JH, Nobeoka K (2002) Creating and managing a high-performance knowledge-sharing network: the toyota case. Strateg Manag J 21(3):345–367
22. Kale P, Singh H, Perlmutter H (2000) Learning and protection of proprietary assets in strategic alliances: building relational capital. Strateg Manag J 21(3):217–237
23. Oliver W (1985) The economic institutions of capitalism. Antitrust Bulletin

Chapter 4
Influence of the Balanced Global Prospective Payment System for Behavior of Small and Medium Medical Institutions

Ziyang Geng, Li Zhang and Yanting Wang

Abstract The pilot effect of global prospective payment system is mainly directed to reduce the medical expenses of individual medical institutions. From the perspective of balanced regional medical resources utilization, a mathematical model of balanced global prospective payment system is built combining the level of medical resource utilization and quota of medical insurance funds. For small and medium-sized medical institutions, under such a mechanism, analysis of income maximization conditions and influence of changes of funds distribution standard have been made. It is put forward that implementation of the mechanism aiming at common diseases and putting standard of distribution of health insurance funds on lower level will contribute to weaken related excessive medical treatment and promote the attractiveness of small and medium-sized medical institutions so as to promote equilibrium of medical resources utilization.

Keywords Medical resources · Equilibrium of utilization · Global prospective payment · Small and medium-sized medical institutions

4.1 Introduction

From Arrow [1], Information asymmetry problem about the uncertainty of disease occurrence and medical effect have been an important issue for external intervention to medical market. Comparing with patient's concealing disease informations, medical institution's information improper use problem about medical process and effect, typical performance is doctor's induced demand behavior [8], worth more

Z. Geng
Management School, Chengdu University of TCM, Chengdu 611137,
People's Republic of China

L. Zhang (✉) · Y. Wang
Business College, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: zhangliscu@126.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_4

attention. Generally speaking, information inappropriate use behavior in medical institutions raises patients' medical cost which will make patients change their hospitals to visit. When the information inappropriate use problem appear everywhere in whole medical system, with medical cost rising generally, patients will choose hospital depending on institution level but not on cost. This issue can aggravate the situation of unbalanced utilization of medical resources. For example, it is difficult to see a doctor in large hospitals.

In Britain, the "gatekeeper" mechanism can force patients' behavior to match disease and ability of primary medical institutions. This mechanism will make patients' flow more reasonable and promote balanced utilization of medical resources. Related research shows that the "gatekeeper" system can really enhance the quality and efficiency of public health services in China [9]. It is a pity that "gatekeeper" mechanism can not implement soon in China. A few cities, such as Shanghai and Chengdu, implement a "soft gatekeeper" mechanism with making contracts between community health service organizations and residents. Such "soft gatekeeper" mechanism needs good reputation from community health service institution. Medical institutions are just right lack of good reputation in China.

Primary community health service institutions and patients are both unable to shunt patients effectively which make it has a strong practical significance that how to motivate medical institutions to actively guide patients for reasonable medical choice. Medical institutions need to reduce their moral failure behavior level, such as improper use of information.

In the medical market, the power of morality is always there. Hospital administrators and doctors are always determine their own behavior corresponding to the weights of individual inner moral pursuit, society's expectations for medical morality and economic benefits [10]. Under appropriate economic incentives, it could be possible to reduce medical institutions' moral failure behavior level. This economic incentive relates to public funds. Compared with financial subsidies, medical insurance funds and medical institutions have more professional and deep connection. Further more, economic incentives using medical insurance funds is easy to depend on the number of patients and medical services. This paper will focus on the issue that using medical insurance funds to implement economic incentives.

In China, current medical insurance payment system aggravates induced demand behavior allowing reimbursement in accordance with actual medical service items. Reform consensus believe that paying for actual items need to be replaced with other systems including global prospective payment system, paying for disease type, paying for service unit, paying for capitation. Under such consensus, pilot projects about medical insurance payment system reform, mainly about global prospective payment system, have been made in some cities. These projects are limited in different individual medical institution and do not involve using regional medical resources. The result is that effect of these projects mainly reflected in the suppression of medical expenses rose too fast and the promotion effect for balanced utilization of medical resources is not obvious. Domestic literatures about global prospective payment system are mainly summary of those pilot projects with no study about operating mechanism of this system [4].

The purpose of foreign literatures about global prospective payment system is mainly controlling medical expenses and their study focus is on reasonable amount of medical insurance funds received by medical institutions [5, 6]. Only a few literatures focus on the actual effect of allocation and utilization of medical resources through global prospective payment system. Taiwan is one of the most successful areas for implementation of global prospective payment system. A study about Taiwan dental department by Chao et al. [2] showed that global prospective payment system can reduce excessive utilization of medical resources through reduce the number of patients and influence medical service structure through concrete system designing. Kreng et al. [7] had measured the impact of global prospective payment system on the distribution fairness of medical resources in Taiwan and found that medical resources are over concentrated in northern Taiwan and big cities, but they didn't pay attention to the issue that how global prospective payment system will influence resource utilization efficiency when medical resources structure has been established. These studies are mainly carried out from the empirical aspects and not only lack of systematic but also not involved research on internal mechanism of the impact of global prospective payment system on the utilization of medical resources.

The supply of medical services in mainland of China is a stable public hospital system. Multilevel health care financing system and urban-rural medical insurance system exist at the same time. These situations are not same as Taiwan. Overall, current domestic and international literatures can not guide to establish a health insurance payment system which is beneficial to health care resources equilibrium utilization in mainland of China.

The main reason of "difficult to see a doctor" in large hospitals maybe the small and medium hospitals are lack of attraction. Therefore, how to improve the attraction of small and medium hospitals is one of the key points to ease the use of medical resources. Gengziyang et al. [3] put forward a framework model of global prospective payment system from the perspective of promoting the balanced utilization of regional medical resources. The model relates hospital's quota of medical insurance fund to their resource utilization degree. Medical institutions can obtain a higher quota only when their resource utilization degree near or equal the regional average degree of medical resource utilization. Based on this framework model, this paper will analyze the effect of such medical insurance fund allocation method on the behavior of small and medium medical institutions and find out whether there is a way to promoting the possibility of advancing equilibrium utilization of medical resources while depress the degree of medical institution's moral failure.

4.2 Revenue Function of Medical Institution Under Balanced Global Prospective Payment System

4.2.1 Balanced Global Prospective Payment System

For specific medical services that are generally available in the region, the regional average medical service quantity corresponding to the unit medical resources is referred to be regional average resource utilization rate (for short average utilization rate). Assuming that the size and demand structure of regional medical resources are unchanged, then the average utilization rate is unchanged.

According to how many resources associated with a specific medical service a medical institution have and how many medical services the institution provide this year, we know the utilization rate which mean the service quantity corresponding to unit resource quantity of the medical institution. Comparing average utilization rate and utilization rate, the degree can be known that the resource of this medical institution is not balanced with the special medical service demand this year. The degree of deviation from the average utilization rate is higher, allocation rate of medical insurance fund to the medical institution related to specific medical service is lower. In this paper, we call such global prospective payment system to be balanced global prospective payment system (for short balanced prepayment).

For specific medical services, medical institutions can get more medical insurance quota by adjusting resource utilization method. The new resource utilization method can affect patients' medical choice by being transformed into induced signal which can be identified by patient. I stands for change intensity of resource utilization method of the medical institution and i stands for induced signal intensity. Assuming that $i = \alpha I, \alpha > 0, \alpha$ stand for the degree of patient distinguish I. $N_1(i)$ stands for the number of patient who receive special medical service in the medical institution this year. $x(I)$ stands for the average special medical service patient receive under new resource utilization method. $S_1 = N_1(i)x(I)$ stands for the total special medical service this medical institution provide this year. By assuming that the scale of the resources related to the medical institution and the specific medical service is unchanged in two years, S_1 and utilization rate are equivalent in measuring the level of resource unbalanced utilization. $w(S_1)$ stands for the medical insurance fund quota related to special medical service the medical institution will get next year. When S_1 is bigger than regional average special medical service quantity, $dw/dS_1 < 0$, otherwise, $dw/dS_1 > 0$.

4.2.2 Revenue Function of Medical Institution

Assuming that new resource utilization method and are both determined this year and function of induced signal will continue from this year to next year. Figure 4.1 is the timing sequence of influence of balanced prepayment.

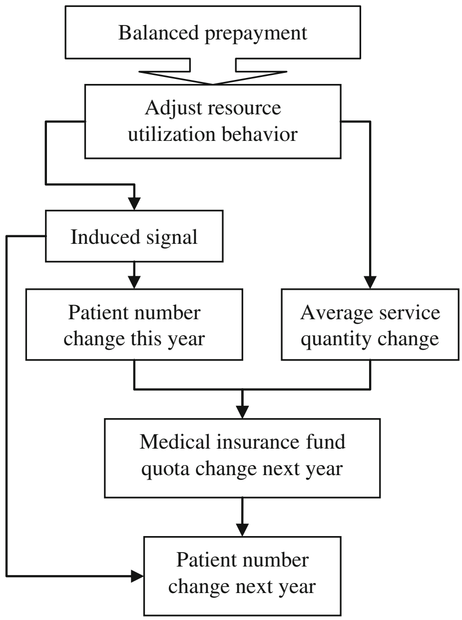


Fig. 4.1 Timing sequence of influence of balanced prepayment

$N(i, w) = N_1(i) + N_2(i, w)$ stands for total patient number of two years. $N_2(i, w) = N_1(i) + N_c(i, w)$ stands for total patient number in next year and $N_c(i, w)$ stands for incremental quantity of patient number in next year. Considering that urbanization increases population year by year, it is assumed that the natural incremental quantity of patient number next year is positive which means $N_c > 0$ when $I = 0$. $S_c = x(I)N_c(i, w)$ stands for incremental quantity of service quantity next year.

It is assumed that the cost of adjustment behavior can be ignored comparing to the cost of resource utilization and the net profits of unit medical service before and after adjustment behavior are both a known constant $k > 0$. $Y(I)$ stands for the total net profit of the medical institution in two years, so

$$Y(I) = kx(I)N(i, w) = kx(I)(2N_1(i) + N_c(i, w)) = k(2S_1 + S_c). \tag{4.1}$$

$\Delta S_1 = S_1|_I = \alpha N_1{}'(i)x(I) + N_1(i)x'(I)$ stands for the marginal effect of adjustment behavior to service quantity this year. $\Delta w_I = \Delta S_1 dw/dS_1$ stands for the marginal effect of adjustment behavior to medical insurance fund quota next year. $\Delta N_{cw} = \Delta w_I \partial N_c(i, w)/\partial w$ stands for the marginal effect of adjustment behavior through to patient number next year. $\Delta N_c = N_c(i, w)|_I = \alpha\partial N_c(i, w)/\partial i + \Delta N_{cw}$ stands for the total marginal effect of adjustment behavior to patient number next year. $\Delta S_c = S_c|_I = x'(I)N_c(i, w) + x(I)\Delta N_c$ stands for the marginal effect of adjustment behavior to incremental service quantity next year.

Then we have

$$\begin{aligned} Y_I &= k(2\Delta S_1 + \Delta S_c) \\ &= k(2(\alpha N_1{}'(i)x(I) + N_1(i)x'(I)) + (x'(I)N_c(i,w) + x(I)\Delta N_c)). \end{aligned} \tag{4.2}$$

4.3 Optimal Conditions for a Given Medical Insurance Fund Distribution Standard

Hypothesis 1 (H1): medical institution is always pursuit higher w by resource utilization adjustment behavior, that is $\Delta w_I > 0$, and patient is always pursuit higher medicare reimbursement amount, that is $\partial N_c(i, w)/\partial w > 0$.

Because of H1, there is always $\Delta N_{cw} > 0$. The main resource utilization problem of small and medium medical institutions is under utilization of medical resources. That is utilization rate is less than average utilization rate. Because of $dw/dS_1 > 0$ is exogenous given, adjustment behavior need to make $\Delta S_1 > 0$ to guarantee $\Delta w_I > 0$.

Hypothesis 2 (H2): reducing $x(I)$ will attract patients and improving $x(I)$ will lost patients. That is $N_1{}'(I) > 0$, $\alpha \partial N_c(i, w)/\partial i > 0$ when $x'(I) < 0$ and $N_1{}'(I) < 0, \alpha \partial N_c(i, w)/\partial i < 0$ when $x'(I) > 0$.

Hypothesis 3 (H3): for incremental patient number, the influence of the change of resource utilization method is higher than it of the change of medical insurance fund.

Hypothesis 4 (H4): changing the amount of service does not affect the medical effect.

Generally speaking, medical institution raises intensity of adjustment behavior only when total income increase. Assuming $Y_I \geq 0$, $Y_{II} < 0$, when I is optimal, according to $Y_I = 0$, we have

$$\frac{Y_I}{x(I)} = 2\left(\frac{x'(I)}{x(I)} + \frac{\alpha N_1{}'(i)}{N_1(i)}\right) N_1(i) + \left(\frac{x'(I)}{x(I)} + \frac{\Delta N_c}{N_c(i,w)}\right) N_c(i,w) = 0. \tag{4.3}$$

We denote $\alpha N_1{}'(i) = x_1 + x_2$, $\Delta N_c = y_1 + y_2$ and make x_1, x_2, y_1, y_2 to be satisfied with $x'(I)/x(I) = -x_1/x_1 N_1(i) = -y_1 N_c(i, w)$. Then Eq. (4.3) can be transformed into

$$\frac{Y_I}{x(I)} = 2x_2 + y_2 = 0. \tag{4.4}$$

Whether a medical institution increases or reduces service quantity under balanced prepayment depends on its historical behavior type but not on interest. So we should analyze the relationship between balanced prepayment and medical institution behavior from perspective how to influence medical institution's inherent behavior type.

4.3.1 Medical Institution Reduce Average Service Quantity

When I is optimal, We have $\varDelta S_c < 0$ by Eq. (4.2) and when $\varDelta S_1 > 0$ we have

$$\frac{\varDelta N_c}{N_c(i,w)} < -\frac{x'(I)}{x(I)} < \frac{\alpha {N_1}'(i)}{N_1(i)}, \tag{4.5}$$

and $x_1 > 0$, $x_2 > 0$, $y_1 > 0$, $y_2 < 0$. To guarantee cross elasticity to average service quantity is greater than 1, $x_2 > 0$ shows the improving degree of $x_1 > 0$, the patient number growth speed corresponding cross elasticity is 1 this year. $x_2 > 0$ can be called strong elastic increasing degree of patient growth speed this year. To guarantee cross elasticity to average service quantity is less than 1, $y_2 < 0$ shows the slowing down degree of $y_1 > 0$, the patient number growth speed corresponding cross elasticity is 1 next year. $y_2 < 0$ can be called weak elastic slowing down degree of patient growth speed next year.

I will be optimal when x_2, y_2 satisfy Eq. (4.4). By that, weak elasticity decline degree of patient growth speed next year is double than strong elasticity increase degree of patient growth speed this year which means patient number rising with average service volume felling needs obvious realization this year for maximizing medical institution's profit. If Eq. (4.4) can not be satisfied, with medicare reimbursement standards unchanged, medical institution can improve to make patient more sensitive for decline in service. When patient population is relative stable, $N_1(i)\,|_I$ will rise and $N_c(i)\,|_I$ will drop and Eq. (4.4) can be facilitated.

4.3.2 Medical Institution Improve Average Service Quantity

By H3, it can be known $\varDelta N_c < 0$ when $x'(I) > 0$. Because natural increment of patient next year is positive, $N_c(i, w)$ can be always positive or be from positive to negative with I increasing.

If $N_c(i, w) > 0$ when I is optimal, by $\varDelta S_1 > 0$, $\varDelta S_c < 0$ we have

$$-\frac{\alpha {N_1}'(i)}{N_1(i)} < \frac{x'(I)}{x(I)} < -\frac{\varDelta N_c}{N_c(i,w)}. \tag{4.6}$$

Similarly, If $N_c(i, w) > 0$ when I is optimal, we have

$$\begin{cases} \dfrac{x'(I)}{x(I)} > -\dfrac{\alpha {N_1}'(i)}{N_1(i)} \\ \dfrac{x'(I)}{x(I)} > -\dfrac{\varDelta N_c}{N_c(i,w)} \end{cases}. \tag{4.7}$$

In both situations we all have $x_1 < 0$, $x_2 > 0$ and $y_1 < 0$, $y_2 < 0$. To guarantee cross elasticity to average service quantity is less than 1, $x_2 > 0$ denotes the slowing down degree of $x_1 <$, the patient number falling speed corresponding cross elasticity is 1 this year. $x_2 > 0$ can be called weak elastic slowing down degree of patient falling speed this year. To guarantee cross elasticity to average service quantity is greater than 1, $y_2 < 0$ denotes the improving degree of $y_1 < 0$, the patient number falling speed corresponding cross elasticity is 1 next year. $y_2 < 0$ can be called strong elastic improving degree of patient falling speed next year.

I will be optimal when x_2, y_2 satisfy Eq. (4.4). By that, strong elastic improving degree of patient falling speed next year is double than weak elastic slowing down degree of patient falling speed this year which means that patient number dropping with average service volume improving should not be obviously realized this year for maximizing medical institution's profit. If Eq. (4.4) can not be satisfied, medical institution can reduce to make patient not sensitive for service improving. When patient population is relative stable, $N_1(i)\,|_I$ will drop and $N_c(i)\,|_I$ will rise and Eq. (4.4) can be facilitate.

4.4 Influence for Medical Institution Behavior by Changing Medical Insurance Distribution Standard

4.4.1 Influence for Medical Institution Profit by Changing Medical Insurance Distribution Standard

Rewrite $N_c(i, w)$ to $N_c(i, w) = A + \int_0^T \Delta N_c dt$. $A > 0$ denotes the natural increasement of $N_c(i, w)$ and T denotes length of period. dw/dS_1 rising will make $\Delta N_{cw} > 0$ rising while not influence $\alpha\partial N_c(i, w)/\partial i$, so ΔN_c will rising. As the result, $N_c(i, w)$ and $\Delta N_c/N_c(i, w) = 1/((A/N_c + T)$ will both rising. Similarly, dw/dS_1 dropping will make $N_c(i, w)$ and $\Delta N_c/N_c(i, w)$ both reducing.

Using superscript b and l denotes respectively the before and after situation of dw/dS_1 changing. Medical insurance distribution standard dw/dS_1 changing will not influence $N_1(i)$ and $x(I)$. By that, when dw/dS_1 rising, whether $x'(I) < 0$ or $x'(I) > 0$, we always have

$$y_2{}^b = (\frac{x'(I)}{x(I)} + \frac{\Delta N_c{}^b}{N_c{}^b(i, w)})N_c{}^b(i, w) < (\frac{x'(I)}{x(I)} + \frac{\Delta N_c{}^l}{N_c{}^l(i, w)})N_c{}^l(i, w) = y_2{}^l, \tag{4.8}$$

then Y_I will rising with $2x_2 + y_2$ rising. Similarly, dw/dS_1 decline makes $y_2{}^b > y_2{}^l$ and then Y_I will dropping with $2x_2 + y_2$ dropping.

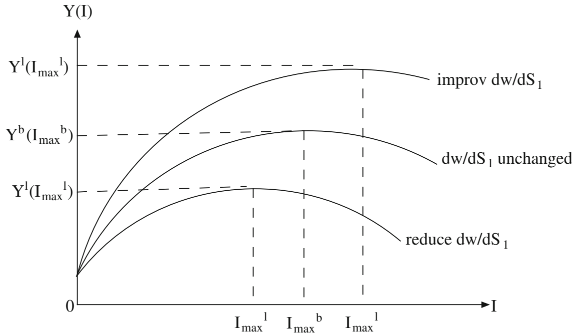


Fig. 4.2 Influence to profit of adjustment behavior by changing dw/dS_1

The optimal value of I will be denoted as $I_{\max}$. Improving dw/dS_1 will make curve $Y(I)$ to move anti-clockwise and $I_{\max}{}^l > I_{\max}{}^b$. Reducing will make curve $Y(I)$ to move clockwise and $I_{\max}{}^l > I_{\max}{}^b$, as Fig. 4.2.

4.4.2 Measures for Medical Institution

The measures for medical institution mainly include changing α and changing I.

Profit will falling when reduce dw/dS_1, medical institution will have the motivation to make profit curve back to the state when dw/dS_1 unchanged to make up for loss or gain higher returns. This goal can be achieved by changing α to improve Y_I. It needs to improve α to make Y_I rising when $x'(I) < 0$ and to reduce α when $x'(I) > 0$. After changing α, for better profit, medical institution can reduce I when new profit curve is under original profit curve or improving I when new profit curve is on original profit curve.

When dw/dS_1 rising, medical institution have no motivation to α change because it will certainly get more profit comparing to α unchanged. Considering $I_{\max}{}^l > I_{\max}{}^b$ in new profit curve, medical institution can expand its profit through improving I.

4.5 Method to Waken Excessive Medical Treatment by Balanced Prepayment

Based on above analysis, there are two ways to weaken excessive medical treatment. One way is making Eq. (4.4) to be satisfied easier when reduce average service quantity with degree of patient identification for the strength of medical institutions changing their resource utilization mode (α) is given. It needs patient number changing to occur more easily in two years. Another way is to make change to weaken excessive medical treatment which means improving α more or reduce less α. According to the previous analysis, there are two methods to promote the realization of these two ways.

The first method is to implement balanced prepayment for common diseases rather than difficult diseases. With α is given, Eq. (4.4) is workable only when patient is sensitive for reducing average service quantity or lags in response for improving average service quantity. Response sensitivity was correlated with patient population characteristics. Through choosing appropriate medical service type, balanced prepayment can select patients indirectly to influence the difficulty of maximizing the benefits of medical institutions. When α is given, patients with higher degree of cognition of diseases are more sensitive of service quantity change. When implementing balanced prepayment aiming at common diseases, patients can response positively to the reduction and improvement of service quality which will make Eq. (4.4) workable easier with reducing service quantity and harder with improving service quantity. It will drive medical institutions to reduce service quantity so that be in favor of weakening relative excessive medical treatment. In contrast, because patients' cognitive basis is weak, the positive response to service quantity change is difficult to be excited by balanced prepayment for difficult diseases so that medical institutions improve service quantity will achieve maximum benefits more easily which is not conducive to weaken excessive medical treatment.

The second method is to reduce health insurance allocation standards for common diseases. Based on previous analysis, reducing medical insurance distribution standards (reducing dw/dS_1) can make medical institution who reduce/improve average service quantity has motivation to advance/decrease α. With implementing balanced prepayment for common diseases, because patients have certain cognition to common diseases which lead to the situation reducing α is harder than improving α, reducing dw/dS_1 will bring change of α more conducive to weaken excessive medical treatment. In contrast, it is easier to reduce α for difficult diseases so that reducing dw/dS_1 will aggravate excessive medical treatment.

4.6 Conclusion

For mechanism designing, the objective of balanced prepayment is promoting balanced utilization of medical resources but not patient rational flow. Behaviors of medical institutions and patients co-effect the medical resource utilization. The behavior of medical institutions is path-dependent. Behavior of medical institutions whether produce well-meaning influence to patients' behavior or not depends on its historical behavior model objectively. Given the behavior model, medical institutions consider behavior degree but not behavior direction to maximize their profit. Patients flow might be more rational or more non-rational influenced by behavior of medical institutions. Associating with this situation, it is necessary to consider implementation conditions and methods of balanced prepayment to meet the public purpose of promoting patients rational flow.

For small and medium medical institutions, implementing balanced prepayment for common diseases and keeping health insurance allocation standards on lower level can help to guide patient flow from large medical institutions to them. Common disease patients swarming into large medical institutions is one of the key issues causing the problem of "Difficult to see a doctor". Meanwhile, resource waste associating to common diseases is a highlight resource utilization problem in small and medium medical institutions. For both the "Difficult to see a doctor" problems and resource waste problem associating to common diseases, implementing balanced prepayment can be useful. Specially, medical institutions wish to reduce information asymmetry between doctors and patients (raise α) when medical insurance distribution standards is reduced. Because patients have certain knowledge base for common diseases, raising can stimulate patients' initiative to match their diseases with service ability of different medical institutions. It is that balanced prepayment has certain function of primary medical resources matching.

Acknowledgments This paper is sponsored by: (1) Sichuan Science and Technology Project–Soft Science Research Project (2014ZR0133); (2) Sichuan Philosophy and Social Science Emphasis Research Base Project (Xq15C06); (3) Key Research Project of Education Department of Sichuan Provincial (15SA0029); (4) Science and Technology Development Fund Project of Chengdu University of TCM (RWYY1403 & RWMS201304).

References

1. Arrow KJ (1963) Uncertainty and the welfare economics of medical care. Am Econ Rev 53(5):941–973
2. Chao HL, Lyu J (2010) A study of dental services in Taiwan before and after global budgeting. Int J Electron Bus Manag 8(2):139
3. Geng Z, Zhang L, Zhong S (2013) The functionality extension of medicare global-budget: adjustment of medical resources supply structure and regional balance. Chin Health Econ 32(4):9–11 (in Chinese)
4. Han JJ, Hu D (2012) Research on inovation for medical insurance payment to change the "expansive treatment" phenomenoninvestigation on medical insurance payment reform in Changchun. J Northeast Normal Univ (Philosophy and Social Sciences) 2:49–53 (in Chinese)
5. Holahan J, Blumberg LJ, Zuckerman S (1994) Strategies for implementing global budgets. Milbank Q 72:399–429
6. Jegers M, Kesteloot K et al (2002) A typology for provider payment systems in health care. Health Policy 60(3):255–273
7. Kreng VB, Yang CT (2011) The equality of resource allocation in health care under the national health insurance system in Taiwan. Health Policy 100(2):203–210
8. Mc Guire TG (2000) Physician agency in handbook of health economics, under the direction of anthony. In: Culyer AJ, Newhouse JP, vol 1, pp 463–536
9. Shi L, Lee DC et al (2015) Community health centers and primary care access and quality for chronically-ill patients-a case-comparison study of urban Guangdong Province, China. Int J Equity Health 14(1):1
10. Spielman BJ (1988) Financially motivated transfers and discharges: administrators' ethics and public expectations. J Med Humanit Bioeth 9(1):32–43

Chapter 5
A Study of Urban Natural Disaster Vulnerability Assessment Based on PCA-TOPSIS Method

Xianming Xiong, Yi Lu and Qiulin Li

Abstract This article established the urban natural disasters vulnerability evaluation index system from the perspective of disaster system's carriers that cover economic, demographic characteristics, urban morphology and disaster management, etc. In this paper, Principal Component Analysis (PCA) and TOPSIS methods were adopted to build the evaluation model, through which the vulnerability of 21 cities in Sichuan Province to natural disasters were assessed. Moreover, we made comparative analysis among the 21 cities mainly focused on the overall vulnerabilities and further provided some useful advice on enhancing the disaster response capacity for city managers.

Keywords Natural disaster · Vulnerability assessment · PCA · TOPSIS · Sichuan Province

5.1 Introduction

Since the management capacities of disaster prevention and reduction have direct impact on people's life and property security, which also relate to the stability of social operation, the urban disaster prevention and control as well as emergency response issues are highly concerned. Indeed, the urban natural disasters vulnerability assessment can fulfill the task by estimating the city's natural disasters capacity and find out the weekness in city disaster management.

Up to now, there are plenty of research production concentrated on vulnerability assessment. Take climatic variation for example, systematic study about the urban vulnerability due to climate change were conducted by research organizations and a large number of scholars in Europe and America. And they provided profound

X. Xiong · Y. Lu (✉) · Q. Li
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: luyiscu@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_5

changes on the management decision-making mechanism as well as scientific basis for policy formulation and modification [5].

The method Common Methodology of seven-step vulnerability assessment proposed by the Intergovernmental panel on climate change (IPCC) was already applied in 24 countries, which can be used to assess the vulnerability of the region, the environment, and the infrastructure [3]. America national Research Project (US Country Studies Program) also systematically studied the vulnerability assessment, and established an evaluation method of sub-4-step implementations [4]. Based on the IPCC technical guidance of vulnerability assessment program, United Nations Environment Program (UNEP) compiled manuals to assess the impact of climate change and put forward measures for economic-society adaptation. The manuals provided a convenient and scientific evaluation guide for vulnerability assessment, and can be applied to different objects in different types of area [7, 10]. Based on the World Health Organization and the relevant international authority of the vulnerability assessment indicators, Tyndall Center for Climate Change Research established a vulnerability assessment system at the country level [8].

Domestic researches on vulnerability began from the ecological environmental fragility and the vulnerability of water resources in the 1960s [1, 6]. It was not until 1980s that vulnerability assessment studies of natural disasters had made preliminary progress, when research methods were merely qualitative analysis and the establishment of conceptual models, while quantitative analysis was used very little [10, 11]. Later, Yu and Han [9] used the method of AHP, and conducted a systematic quantitative study of vulnerability assessment of urban natural disasters. Fan [2] proposed vulnerability index evaluation method aiming at the regional hazard bearing body, and made specific direction in setting up index system and method for determining the weight coefficients. They also made a preliminary study on vulnerability assessment model.

From the perspective of disaster system carriers, this paper established the evaluation index system of city natural disasters concerning economic, demographic characteristics, urban morphology, disaster management factors and etc. Using principal component analysis (PCA) and TOPSIS methods, we build the evaluation model for urban natural disasters assessment and contrasted the natural disaster vulnerability levels in 21 cities of Sichuan Province.

This paper innovative proposed a vulnerability assessment index system and fine quantitative evaluation model with good fitness, which contribute to scientific decision-making in urban management. Through conducting field researches to 21 cities in Sichuan Province and doing quantitative analysis based on the data collected, we identified the problems existed in urban natural disasters responses vulnerability of Sichuan, and refined more universal countermeasures for urban disaster prevention and reduction, which can lead to better city emergency management.

5.2 Vulnerability Assessment Systems

The assessment of urban natural disaster vulnerability needs a study from a holistic perspective. On the basis of existing assessment methods and indicators systems, this paper constructs the corresponding evaluation model combining PCA-TOPSIS method.

5.2.1 Assessment Systems

According to the existing research results, this article constructed an index system (Table 5.1) from five aspects of disaster management system: infrastructure, macroeconomic society, population, urban structure and morphology. Compared with the past, the index system constructed in this paper has the following three features:

(1) Not involved in a specific disaster, but evaluates its vulnerability to natural disasters from the disaster bearing body's own characteristics.
(2) For the city itself, the paper argues the most primary factors which affects the vulnerability is not the characteristics of natural systems, but its human elements. So we should fully consider the influence of social economic factors and human factors on urban vulnerability.
(3) Emphasize the attributes of human beings to resist disasters, especially does vulnerability assessment for the urban population features, which is used to measure a person or group to response, withstand and recover from the impact of disasters.

5.2.2 Principal Components and the Corresponding Weights

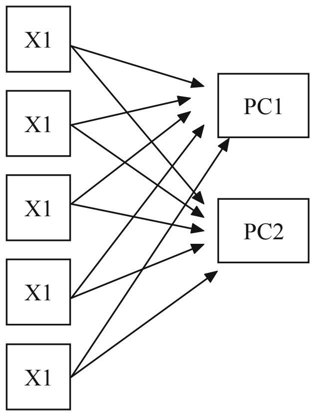
There are many urban natural disaster vulnerability evaluation indicators, which may contain similar information. If these related indicators are included in evaluation, the evaluation results will directly be affected. So it is necessary to choose the independent and representative indicators as vulnerability evaluation indexes. Using PCA can solve the above problems effectively. PCA is a good method in data dimension reduction, which can successfully convert a large number of relevant variables into a set of very few unrelated variables. These unrelated variables are usually called Principal-component. For example, If there are five related environment variables, using PCA can transform them into two independent component variables and retain the information of the original data set as much as possible, as shown in Fig. 5.1.

Assume k and n represent the number of cities and indicators respectively. $x_{ij}(i = 1, 2, \ldots, k,\ j = 1, 2, \ldots, n)$ is the value of the ith city under the jth indicator.

Table 5.1 Vulnerability assessment indicators of urban natural disasters

Primary indicators	Secondary indicators
Infrastructure	Domestic road density
	Annual per capital electricity consumption
	Annual per capital water consumption
Economy	Per capital GDP
	Economy density
	Agricultural output share of GDP
Disaster response	Disaster relief organization
	Per capital insurance coverage
	The number of beds in ten thousand people
Urban morphological structure	Regional building coverage ratio
	Green coverage
	Housing construction area proportion
Public's awareness to disaster	R&D expenditure in GDP
	Annual per capital spending on education
	Number of teachers in ten thousand people
	Public disaster publicity and education
Disaster Management System	Administrative bodies' impeccable level
	Impeccable degree of disaster contingency plans
	Public participation in decision-making
Population structure	The following minimum living security line-population ratio
	The proportion of the total population flow
	Population density
	The proportion of the population over 60 years old

Fig. 5.1 Model of *PCA*



These values can constitute matrix $X_{k\times n}$, from which we can calculate the correlation coefficient matrix R. Then we calculate the eigenvalues and the corresponding orthogonal feature vectors $\overrightarrow{b_1}, \overrightarrow{b_2}, \ldots, \overrightarrow{b_k}$ shows the value of principal component, then we can obtain the value of each principal component by Eq. (5.1).

$$\begin{bmatrix} Y_1 \\ \vdots \\ Y_k \end{bmatrix} = \begin{bmatrix} b_{11} & \ldots & b_{1k} \\ \vdots & \ddots & \vdots \\ b_{k1} & \ldots & b_{kk} \end{bmatrix} \begin{bmatrix} X_1 \\ \vdots \\ X_k \end{bmatrix}. \tag{5.1}$$

Each principal component corresponds to one explained variance, which contains the information of the original variables. The value of explained variance is greater, the principal component contains more information. Therefore, the weight of principal components can be calculated according to the amount of information they contain. Through that way, we can make full use of original data information. In order to clearly express the weight of principal components, we need to do the normalized processing for principal components. The results show the weights of principal component about urban natural disaster vulnerability assessment (Eq. (5.2)), where s_i^2 means the explained variance value of the ith principal component.

$$\varpi_i = \frac{s_i^2}{s_1^2 + s_2^2 + \cdots + s_n^2} \quad (i = 1, 2, \ldots, n). \tag{5.2}$$

5.2.3 Assessment Values Sorting

TOPSIS has not strict limitation in data distribution, sample size and index attributes. With using the comparison information effectively, the method also has intuitive geometric meaning. Therefore, it can be fully applied to the assessment of urban natural disaster vulnerability. The basic steps of the method are shown in Fig. 5.2.

5.3 Case Study

We conducted research on cities and prefectures of Sichuan Province, then acquired data and did quantitative analysis. According to principal component analysis and TOPSIS sort method, we made vulnerability assessments by indicators of economic, social, and disaster management capabilities.

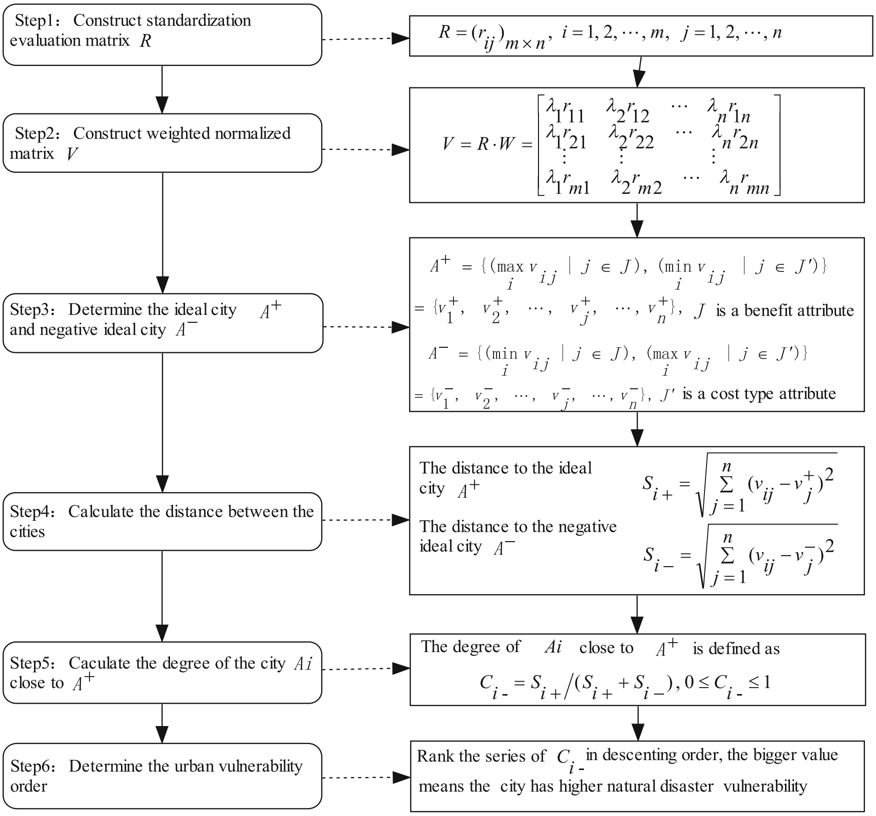


Fig. 5.2 Basic framework of urban natural disaster vulnerability assessment based on *TOPSIS*

5.3.1 Study Area

Sichuan Province is located between longitude 97°21′–108°33′ and north latitude 26°03′–34°19′ (Fig. 5.3). It has eighteen cities (Chengdu, Mianyang, etc.) and three autonomous prefecture (Aba, Ganzi and Liangshan). In Sichuan Province, The west is highland and mountains within over 3,000 m elevation, while the eastern part is the basin and hills, whose altitude is between 500 and more than 2000 m.

5.3.2 The Score of Vulnerability Indexes

Using PCA, we analyzed 21 cities' disaster vulnerability under 23 indicators. According to the eigenvalue and the accumulated variance contribution rate, we obtained five principal components (Table 5.2). The cumulative variance contribution ratio

Fig. 5.3 21 cities and prefectures in Sichuan Province

Table 5.2 Eigenvalue and the accumulate variance contribution rate

The principal components	The eigenvalue	The variance contribution rate (%)	The cumulative variance contribution rate (%)	The value of weight
1	28.754	48.255	48.255	0.545
2	11.203	19.13	67.385	0.216
3	7.208	11.299	76.684	0.128
4	3.403	6.49	85.174	0.073
5	1.214	3.408	88.582	0.038

of the five principal components was more than 88 %, basically kept the important information of original indexes. Principal component 1 was mainly about urban governance information, principal component 2 mainly about economic development, principal component 3 mainly about information on population characteristics, principal component 4 mainly about information on disaster management, and the principal component 5 mainly about information on urban infrastructure.

In Table 5.3, the five principal components' score are given. Some score indexes are negative. The numerical size here doesn't mean the true level in urban governance, economic development, population characteristics etc. But it says the relative position of one city among all selected cities. If the value is positive, that means the city above average, while the negative number shows the city is under the average.

Table 5.3 Scores of principal components

	Urban governance	Economic development	Population characteristics	Disaster management	Urban infrastructure
Chengdu	1.9729	2.2168	−0.9424	2.3746	1.5991
Mianyang	0.6617	1.7248	0.2956	0.9854	1.23
Deyang	1.0373	1.5296	−0.2891	0.8758	0.5967
Nanchong	−0.7676	1.3561	−0.014	−0.3101	0.0691
Bazhong	0.7967	−1.3445	0.2146	−1.2566	−1.9868
Yibin	0.1352	0.973	0.2079	0.5356	1.0816
Panzhihua	2.0947	0.9549	0.427	−0.5092	0.9423
Leshan	1.248	0.8419	0.2593	−0.029	−0.0952
Dazhou	0.6996	0.7632	0.2392	−0.8949	−1.6419
Luzhou	−0.006	0.5123	0.0891	−0.3065	0.7876
Ziyang	−1.721	0.3593	−0.0331	0.1944	−1.7152
Guang'an	−0.3536	−0.0489	−0.0939	−0.8172	−1.5437
Zigong	0.4195	−0.2002	−0.3196	−0.0488	0.993
Neijiang	−1.321	−0.3113	−0.5445	−0.0135	−0.4167
Meishan	0.5274	−0.4648	0.0106	0.0391	0.0785
Suining	−0.2513	−0.5342	−0.3388	−0.4861	0.1819
Guangyuan	−1.4226	−0.574	0.5033	0.2639	−0.2449
Yaan	0.8302	−0.611	0.6437	0.0286	0.2865
Aba	−1.637	−0.9044	1.8801	0.0134	−2.2004
Ganzi	−1.1021	−1.2188	2.0814	−1.0582	−2.1985
Liangshan	0.2188	1.0736	1.2646	−0.6442	0.2268

5.3.3 *The Comparison of Evaluation Results*

Based on the results of PCA, using TOPSIS, we calculated the vulnerability of each city, shown as Table 5.4 and Figs. 5.4, 5.5 and 5.6.

(1) Overall Vulnerability

The prefectures of Ganzi and Aba have the highest vulnerability to natural disasters. The second cities are Guangyuan, Neijiang and Guang'an. While the cities which have lower natural disaster vulnerability are Chengdu, Panzhihua, Deyang, Leshan and Mianyang.

According to the values of natural disaster vulnerability, we define the mild vulnerability is $C < 0.4$, low degree vulnerability is $0.4 < C < 0.55$, moderate vulnerability is $0.55 < C < 0.7$, high vulnerability is $0.7 < C < 0.8$, severe vulnerability is $0.8 < C$. The states of Ganzi and Aba belong to severe vulnerability cities. Guangyuan, Neijiang, Guang'an, Ziyang and Suining are the high vulnerability cities. Nanchong, Bazhong, Yibin, Dazhou Luzhou, Zigong, Meishan, Ya'an, Liangshan are moderate vulnerability cities, while Mianyang, Deyang, Panzhihua, Leshan are low

Table 5.4 Assessment results of 21 cities natural disaster vulnerability

	S^{+}	S^{-}	C	Order
Chengdu	1.8353	3.403	0.3504	21
Mianyang	2.8686	2.408	0.5437	17
Deyang	2.5975	2.5091	0.5087	19
Nanchong	3.8548	1.6709	0.6976	8
Bazhong	3.6326	1.589	0.6957	9
Yibin	3.3048	1.9365	0.6305	15
Panzhihua	2.2743	2.792	0.4489	20
Leshan	2.7219	2.2913	0.5429	18
Dazhou	3.1466	1.851	0.6296	16
Luzhou	3.4789	1.6242	0.6817	10
Ziyang	4.6752	1.4738	0.7603	6
Guang'an	3.8774	1.2199	0.7607	5
Zigong	3.316	1.7537	0.6541	13
Neijiang	4.4395	1.3029	0.7731	4
Meishan	3.3813	1.7156	0.6634	11
Suining	3.8214	1.3089	0.7449	7
Guangyuan	4.6362	1.2355	0.7896	3
Yaan	3.3328	1.841	0.6442	14
Aba	5.055	1.1817	0.8105	2
Ganzi	4.8501	0.853	0.8504	1
Liangshan	3.4365	1.7583	0.6615	12

degree vulnerability cities (Fig. 5.4). And Chengdu is the mild vulnerability city. Therefore, the five cities of Chengdu, Mianyang, Deyang, Panzhihua, Leshan have less vulnerability. This is due to these cities are the most economically developed area of Sichuan Province. Strong economic strength make the local governments can put money and efforts into infrastructure, science and education, cultural undertakings and disaster management. And the public also have more access to a good education, which can improve people's consciousness and ability to disaster prevention and reduction. That means good education can effectively reduce the level of regional natural disaster vulnerability.

(2) Urban Governance

From the perspective of urban governance vulnerability (Fig. 5.4), Ziyang, Aba, Guangyuan, Neijiang and Ganzi are the worst, while Panzhihua, Chengdu, Leshan and Deyang are the best. The improvement of urban governance will affect the work of disaster prevention and reduction, and low level of urban governance will make the government difficult to cope with the sudden natural disasters.

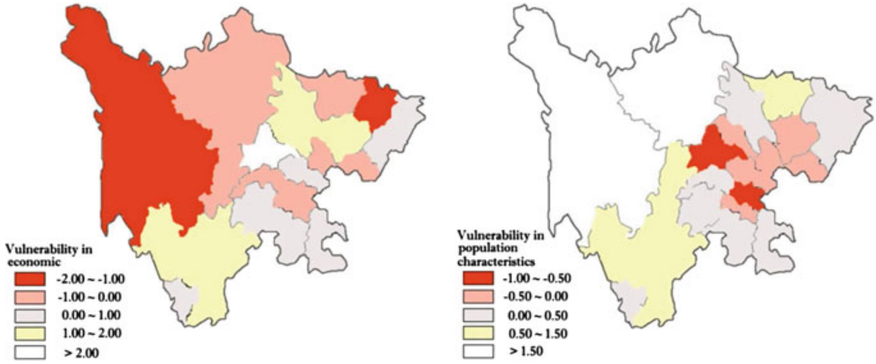


Fig. 5.4 Overall vulnerability and vulnerability in urban governance

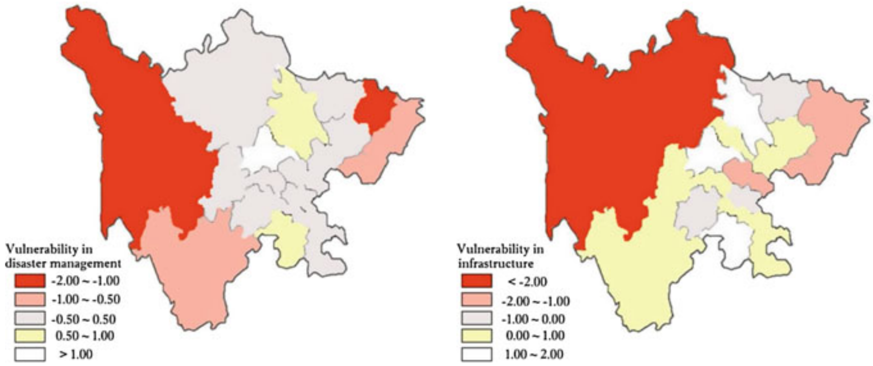


Fig. 5.5 Vulnerability in economic development and population characteristics

(3) Economic Development

From the perspective of economic development vulnerability (Fig. 5.5), Ganzi and Bazhong are the worst cities, while Chengdu, Mianyang, Deyang and Nanchong are the best. The level of economic development, will directly affect the city's investment in disaster prevention and reduction work. Lower investment in work is bound to decrease the effect of disaster prevention and reduction. The economic strength of Ganzi and Bazhong relatively lag behind other cities, and because of they having a higher proportion of agricultural production in their economic structure, this two cities have high vulnerability in facing disasters.

(4) Population Characteristics

From the perspective of population characteristics vulnerability (Fig. 5.5), Ganzi and Aba are the best, while Chengdu and Neijiang are the worst. It may be related to the floating population and the population density in the two cities. In addition, with rapid economic development and population clustering, the office building and resi-

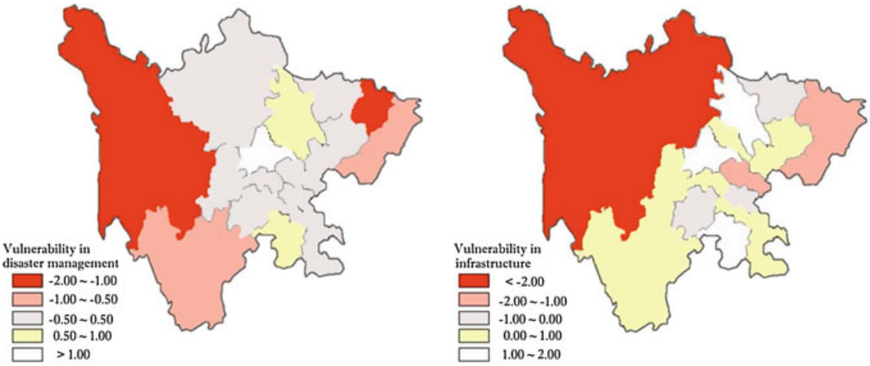


Fig. 5.6 Vulnerability in disaster management and infrastructure

dents' housing area of Chengdu are increasing, which makes the city being exposed to the highest vulnerability in facing natural disaster.

(5) Disaster management

Disaster management contains disaster preparedness, public awareness of disasters, health care, public insurance, etc. From this perspective (Fig. 5.6), the cities of Aba, Liangshan, Ganzi, Bazhong, Ziyang and Dazhou have worst vulnerability, while Chengdu, Mianyang and Yibin are the best cities. In the actual investigation, we found the three cities pay close attention to the cultivation of public consciousness on disaster. The three cities have disaster management system, such as Disaster Emergency Handling Decision System, which can make them realize the digital management. In addition, compared to other cities, the three cities have more professional relief teams and volunteers.

(6) Urban Infrastructure

From the perspective of urban infrastructure (Fig. 5.6), Chengdu, Mianyang, Deyang and Yibin are the best, while Ganzi and Bazhong is the worst. Completeness of urban infrastructure is the basic guarantee against natural disasters. Due to Chengdu, Mianyang, Deyang and Yibin have done well in the aspects such as roads, electricity and water. In these respects, the four cities have stronger ability to withstand disasters.

5.4 Conclusions

Vulnerability assessment is a very important way to estimate the city's ability to respond to natural disasters. Instead of involving specific hazard types, this paper targeted at the support system of the city itself. From the aspects of socioeconomic and cultural, this paper established the assessment index system of urban natural disasters vulnerability. Based on the samples of 21 cities in Sichuan Province, the evaluation of urban natural disaster vulnerability was carried out. The research finding showed that the development of society and economy is harmoniously. The results also revealed that improvement in urban governance, disaster management and infrastructure are an effective way to reduce the city's vulnerability to disasters.

Despite the practical value in analyzing the disaster vulnerability of the selected 21 cities in Sichuan Province, the theoretical basis of vulnerability to natural disasters is weak and indicator system is insufficient, which limit further development of vulnerability studies. Therefore, further studies will concentrate on vulnerability theory extension, index system perfection, and new approach to vulnerability studies.

Acknowledgments This research is supported by the Program of the Social Science Foundation of Sichuan (Grant No. SC15C016). The authors are also grateful to Sichuan University for providing research funding (No. 2016SCU11036; No. skqy201640).

References

1. Chen Y, Niu Z et al (2014) Seismic vulnerability assessment of water supply network in Tianjin, China. Front Env Sci Eng 8(5):767–775
2. Fan YX (2008) Comprehensive evaluation of regional disaster bearing body's vulnerability. Rock Mech Eng 01(4):63–67
3. Füssel HM, Klein RJ (2006) Climate change vulnerability assessments: an evolution of conceptual thinking. Clim Chang 75(3):301–329
4. Joseph J (2013) Measuring vulnerability to natural hazards: a macro framework. Disasters 37(2):185–200
5. Kelly PM, Adger WN (2000) Theory and practice in assessing vulnerability to climate change andfacilitating adaptation. Clim Chang 47(4):325–352
6. Xu X, Xu L et al (2015) Integrated regional ecological risk assessment of multi-ecosystems under multi-disasters: a case study of china. Env Earth Sci 74(1):747–758
7. Yang S, He S et al (2015) Screening of social vulnerability to natural hazards in China. Nat Hazards 76(1):1–18
8. Yi L, Zhang X et al (2014) Analysis of social vulnerability to hazards in China. Env Earth Sci 71(7):3109–3117
9. Yu NX, Han CF (2013) Analysis of urban disaster emergency management index based on analytic hierarchy process. Sci Disaster 28(3):152–157
10. Zhou Y, Li N et al (2014) Assessment of provincial social vulnerability to natural disasters in China. Nat Hazards 71(3):2165–2186
11. Zhou Y, Liu Y et al (2015) Integrated risk assessment of multi-hazards in China. Nat Hazards 78(1):257–280

Chapter 6
The Support System for a Visual Impaired Person Using Laser Eyewear

Yuko Shimomura, Hiroyuki Kawabe, Hidetaka Nambo, Shuichi Seto, Makoto Suzuki and Mitsuru Sugawara

Abstract We construct a system for a visually impaired person. On our system, an image is input by a camera, is transformed by an image conversion system, and is provided to the visually impaired person by an eyewear like glasses. If this system is used, a person can move with the eyewear, and also can watch a scene in the position of line of sight. In the eyewear composed of our system, which is made by QDLaser Inc., the image is projected directly onto a retina. QDLaser Inc. has worked on a small-sized scanning optics to be installed inside the glass frame, and has developed the eyewear named Retinal Imaging Laser Eyewear with the trademark of RETISSA. One of remarkable features of RETISSA is focus free. Regardless of the function of a crystalline lens and eyesight, the wearer can see laser scanned full-color image captured by a digital camera installed in the center of the frame connected to a controller. One of other features of RETISSA is an attractive appearance of eyewear. RETISSA also enables universal design like sunglasses and corrective glasses and realizes complete AR. We explain the system and this eyewear.

Keywords A visual impaired person · The support system · Laser Eyewear

6.1 Introduction

In Japan, as elderly people's population increases, illnesses caused by aging are also increase. Most of the illnesses are accompanied by an obstacle of sense, such as a visual impairment, a hearing impaired, a tactile sense obstacle, a sense-of-smell

Y. Shimomura (✉) · H. Kawabe
Kinjo University, Hakusan 924-8511, Japan
e-mail: shimo@kinjo.ac.jp

H. Nambo
Kanazawa University, Kanazawa, Japan

S. Seto
Kinjo College, Hakusan 924-8511, Japan

M. Suzuki · M. Sugawara
QDLaser, Inc., Atsugi, Kanagawa, Japan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_6

obstacle and a taste disorder. In visually impaired persons, the visual acuity and the contrast sensitivity are reduced. These reduced visual functions have a large impact on their quality of life [1, 2, 10]. The visually impaired persons of retinitis pigmentosa are from 30,000 to 60,000 by the number of Specified-diseases medical recipient, and age-related macular degenerations are about 690,000 [11]. According to Act on Welfare of Physically Disabled Persons of Japan, people supported by law are only ones whose corrected eyesight is under 0.2 or ones whose lack of visual field is more than half. On the other hand, law gives the night blindness no support. Under such situations, various systems with head mounted display (HMD) have been proposed and prototyped as aids for the low vision and the tunnel vision [6]. In these studies, all studies are carried out with HMD composed with the liquid crystalline display and are not for the night blindness. In this paper, we explain our system that is not composed of the liquid crystalline display but the scanning laser ophthalmoscope and report results about application of our system on the night blindness.

In the second section, we describe about the visual impairment. In the third section, we show our HMD, "Retinal Imaging Laser Eyewear". In the fourth section, we explain experiments and results. In the final section, we describe the concluding remarks.

6.2 Impairment

The vision is classified into four categories, eyesight, a visual field, a sense of color, and an adaptation to luminosity. The classification of obstacles is shown in Fig. 6.1. For the impairment of eyesight, the typical symptoms are low vision and blindness. Even if the eyesight is corrected properly, the vision is not clear, and the eyesight keeps weak or is lost. In the visual field impairment, some areas of the visual field are lack and corresponding areas cannot be seen. The typical symptoms are a tunnel vision and a central scotoma. The color blindness cannot distinguish colors such as red from green or blue from yellow. The adaptation to luminosity is the light and

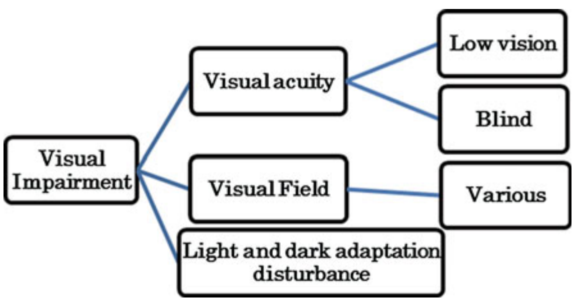


Fig. 6.1 The kind of vision obstacle

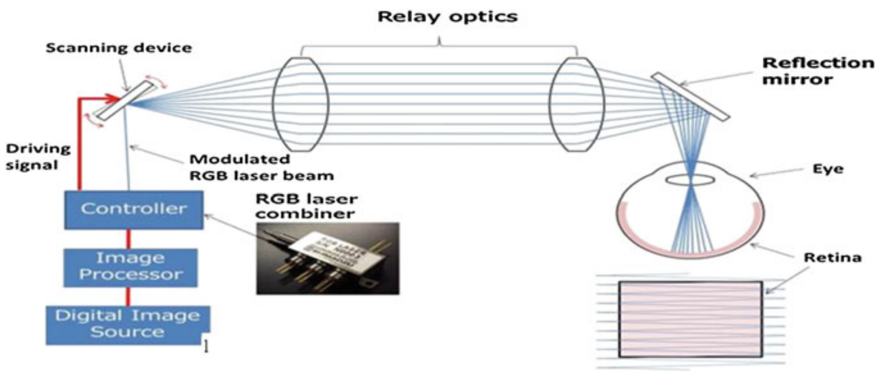


Fig. 6.2 Standard configuration of retinal laser imaging

dark adaption disturbance. When such patient goes into a light place from a dark place or vice versa, he/she loses one's sight.

6.3 Retinal Imaging Laser Eyewear

The process of scanning laser light on the retina was first used to develop the scanning laser ophthalmoscope (SLO). In the SLO, the laser beam is scanned two-dimensionally through the pupil of the eye onto some part of the retina. A tiny spot is focused onto the retina and is swept over it in a raster pattern. Instead of viewing a screen, the user has the image scanned directly into the eye.

Figure 6.2 shows a standard configuration of retinal laser imaging. The RGB laser combiner inside the controller box provides a laser beam consisting of aligned red, green and blue light, each of which is modulated according to the video signal from the image processor connected to the digital image source.

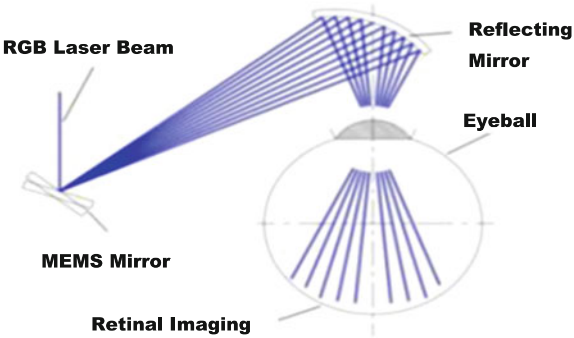
6.3.1 Developed an Eyewear Named Retinal Imaging Laser Eyewear

Under the concept of making VRD with an attractive appearance, we worked on a small-sized scanning optics to be installed inside the glass frame, and developed an eyewear named Retinal Imaging Laser Eyewear with the trademark of RETISSA.

As shown in Fig. 6.3, RETISSA is the eyewear connected to a pocket-sized controller with a sealed line 4 mm in diameter combining an optical fiber and electric lines. We replaced the optics of Fig. 6.2 consisting of two lenses and one reflector with only one non-axisymmetric free-surface reflecting mirror as shown in Fig. 6.4.

Fig. 6.3 RETISSA of retinal laser imaging

Fig. 6.4 RETISSA configuration of retinal laser imaging



The free-surface mirror is designed to collimate the RGB semiconductor laser beam scanned by the MEMS mirror and to converge it in the center of the pupil, projecting an image through the pupil onto the human retina. We make the following thing possible.

(1) Reconcile the maximum viewing angle and the minimum size.
(2) Lose a feeling of a foreign substance in sight.
(3) A feeling of a physical disorder also abolishes a wearing person's appearance.
(4) Always equip possible.

It is a MEMS mirror to a light scanning. It was used. The abnormal conditions of the RGB semiconductor laser were directly used for the illuminant. 1024×600 (WSVGA) pixel, aspect ratio 16 : 9.4, a maximum of 50° of level viewing angle, and frame rate 60 Hz, see-through one, and eyewear weight 60 g are realized.

6.3.2 Safety

The safety of laser products is standardized and outlined by the International Electrotechnical Commission (IEC) document 60825-1 [1]. Here, the laser products are

Table 6.1 Each classes division and danger of IEC60825-1

	Long-time observation		Short-time observation		Dispersion reflection	Skin exposure
	Optical instrument	Naked eye	Optical instrument	Naked eye		
Class 1	Safety	Safety	Safety	Safety	Safety	Safety
Class 1M	Danger	Safety	Danger	Safety	Safety	Safety
Class 2	Danger	Danger	Safety	Safety	Safety	Safety
Class 3R	Danger	Danger	Warning	Warning	Safety	Safety
Class 3B	Danger	Danger	Danger	Danger	Warning	Warning
Class 4	Danger	Danger	Danger	Danger	Danger	Danger

classified based on the calculations of Accessible Emission Limit (AEL) using maximum permissible exposure (MPE). IEC60825-1 is based on the ICNIRP Guidelines [10], and MPE is equal to EL in W/cm^2. AEL is the emission limit of the laser product using MPE for the full open pupil. The document of EN-60825-1 in Europe and JIS C 6802-1 in Japan follows the IEC.

IEC60825-1 describes how to treat the additive case of more than two wavelengths. In the Retinal Imaging Laser Eyewear, the safety factor in the worst case scenario for CW mode without aversion response and the laser power of 411 W is calculated as

$$\text{Safety Factor} = 1/(4/385 + 4/385 + 4/77) = 13.8.$$

Since 13.8 is well above 1, the radiation of the Retinal Imaging Laser Eyewear RETISSA belongs to Class 1.

Furthermore, we are performing the following things.

(1) Laser shut down circuit under the failure of MEMS (Already Installed).
(2) Low pass filter to cut the spike current into the laser (To be installed in Dec. 2015).
(3) APC circuit to monitor and control the laser power (To be installed in Dec. 2015).

A class division and danger were displayed on Table 6.1 [11].

6.3.3 The Feature of RETISSA

One of remarkable features of RETISSA is focus free. Regardless of the function of a crystalline lens and eyesight, the wearer can see laser scanned full-color image captured by a digital camera installed in the center of the frame connected to a controller. Therefore, the persons of weak eyesight can see image clearly.

One of other features of RETISSA is an attractive appearance of eyewear. RETISSA also enables universal design like sunglasses and corrective glasses and

Table 6.2 Comparison with other models

Brand name	MOVERIO [6]	Google glass [4]	RETISSA
Company	EPSON	Google	QDLaser
Announcement year	2014	2013	2016
Weight	88 g	43.8 g	60 g

Fig. 6.5 MOBERIO

Fig. 6.6 Google glass

realizes complete AR. Table 6.2 is comparison with other brand's models. Figures 6.5 and 6.6 are each outside.

6.3.4 Image Conversion Control

We have included some picture conversion control in RETISSA. They are a color/monochrome change, light-and-darkness control, luminosity control, and zoom functional control. Since these operations can be performed simply, they can unite with their conspicuousness.

6.4 Experiment and Result

The image conversion system is build into the control device of the retina projection eyewear. Experience evaluations of the eyewear of the retina projection are shown below.

6.4.1 Measurement and Evaluation

We performed pre-measurement interviews, measurements, and post- measurement interview in following order to get evaluation. In our experiments, we do not expect medical level precision because our aim of experiments is to verify the effectiveness of our eyewear.

(1) Pre-measurement interviews

- Personal information (an age, sex, etc.)
- Conditions of vision (eyesight, a visual field, etc.)
- A dominant eye

(2) Measurements of visual field

- Visible range of one-meter away object by the naked eye
- The same as the above with the eyewear

(3) Measurements of the night blindness

- Brightness that a subject begins to see the biggest Landolt ring of one-meter away by the naked eye in a dark darkroom

(4) Post-measurement interview

- Impression about wearing the eyewear.

6.4.2 Pre-measurement Interviews

For the measurements and analysis, we made interviews with each subjects about personal information, the conditions of vision and the dominant eye by which the following experiments were performed.

6.4.3 Measurements of Visual Field

The visible ranges of one-meter away object were measured without/with the eyewear. Unfurling one's arm a person stood one meter away from a subject, and the subject told how wide he/she could see, for examples, a face, shoulders, elbows, wrists, fingertips, and so on.

6.4.4 Measurements of the Night Blindness

The brightness that a subject began to see the biggest Landolt ring of one-meter away were measured without/with the eyewear. A subject sit in a dark room and told the brightness that the biggest Landolt ring of 1 m away was begun to see under gradually increasing luminosity. Then the brightness was registered with a photometer LX-1118, made by Lutron Electronic Enterprise Co., LTD.

6.4.5 Post-measurement Interview

After experience of the eyewear, we made interviews with each subjects about the impressions of the eyewear as one of evaluations.

6.4.6 Result and Discussion

Although the number of the subjects is a few because of the experiment using the first prototype, we had some results. Figures 6.7 and 6.8 shows the situation of experiment and the contribution survey of the night blindness, respectively. This measurement was performed in the ophthalmology in the Asanogawa General Hospital, Japan. We asked patients for cooperation, and then four patients gave allowance to be subjects. Since one of four who was male almost lost his eyesight, he was hardly able to see images displayed on the eyewear. Other one who was male was hemianopsia and told that the resolution was low although this device had enough brightness. And other one who was male had a very narrow visual field, and told that image quality was bad. Another one who was female has weak eyesight with a narrow visual field. She told that the image was bright and clear and that she could clearly see objects with this device. We are going to improve based on these results and to experiment by many subjects.

6.5 Concluding Remarks

With the glasses like eyewear made by QDLaser Inc., we constructed a system for a visually impaired person. On our system, an image is input by a camera, is transformed by an image conversion system, and is provided to the visually impaired person by the eyewear that the image is projected directly onto a retina. The remarkable features of the eyewear are focus free and an attractive appearance. In this paper, we introduced the eyewear and our system, and evaluated our system. We had some good impressions about the eyewear, however did not obtain the effectiveness of

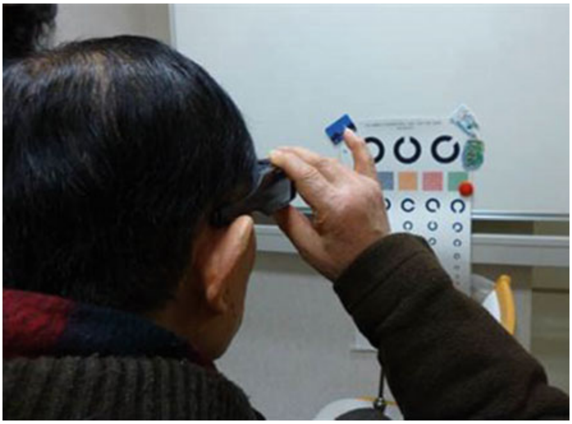


Fig. 6.7 The experiment

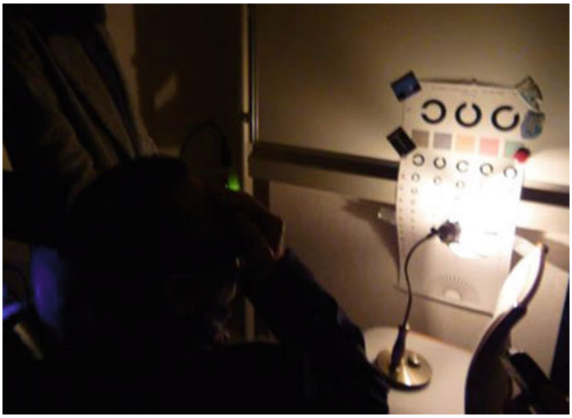


Fig. 6.8 The contribution survey of a night blindness

our system because of the small number of subjects yet. Therefore we are going to improve our system based upon these results and to experiment with many subjects.

We are constructing many support systems until now for the visually impaired person. They are blind person support systems [12], cataract support systems [5], color blindness support systems, visual field impaired support systems, etc. As written with the preface, the fall of QOL of visual impairment is remarkable. There are also many people who cannot do medical treatment with medicine for various reasons. We support the visually impaired person by engineering.

Acknowledgments We got cooperation to Dr. Yutaka Shirao, an Asanogawa General Hospital ophthalmologist, and Ms. Kazue Ozasa of the orthoptist. I appreciate. This work was supported by JSPS KAKENHI Grant number 26350291. And I am thankful to the subjects who cooperated in the experiment, and the students of a seminar. Moreover, cooperation of a visually impaired person's people was also obtained. I appreciate deeply.

References

1. Cahill MT, Banks AD et al (2005) Vision-related quality of life in patients with bilateral severe age-related macular degeneration. Ophthalmology 112(1):152–158
2. Hassell J, Lamoureux E, Keeffe J (2006) Impact of age related macular degeneration on quality of life. Br J Ophthalmol 90(5):593–596
3. Ido T, Saito H et al (2004) Web application based image conversion system for color-blindness. In: Proceedings of the 33rd international conference computers and industrial engineering
4. IEC (2014) Safety of laser products-part 1: equipment classification and requirements. Technical report, IEC
5. Ishikawa K (2008) The safety standards and the work standard of a laser product. O plus E 30(9):940–945
6. Peli E, Luo G et al (2007) Applications of augmented-vision head-mounted systems in vision rehabilitation. J Soc Inf Disp 15(12):1037–1045
7. Saito H, Ido T et al (2004) Image processing algorithm for senile cataract. In: Proceedings of the fifth Asian Pacific industrial engineering and management sytems conference
8. Shimomura Y, Kawabe H, Seto S (2001) Recent advances in multiobjective genetic algorithms for manufacturing scheduling problems. In: 5th international conference on engineering design & automation
9. Shimomura Y, Kawabe H et al (2013) Development of support glasses for various visual field defect. In: Proceedings of the 33rd international conference computers and industrial engineering, p5
10. Stevenson M, Hart P et al (2004) Reduced vision in older adults with age related macular degeneration interferes with ability to care for self and impairs role as carer. Br J Ophthalmol 88(9):1125–1130
11. Yasuda M, Kiyohara Y et al (2009) Nine-year incidence and risk factors for age-related macular degeneration in a defined japanese population: the hisayama study. Ophthalmology 116(11):2135–2140
12. Ziegelberger G (2013) ICNIRP guidelines on limits of exposure to laser radiation of wavelengths between 180 nm and 1,000 μm. Health Phys 105(3):271–295

Chapter 7
Exploring the Most Important Factor of Chinese Sports Charity by Using System Dynamics Simulation

Linling Zhang and Jie Hu

Abstract The development of Chinese sports charity has a long way to go to catch up the steps of that in developed countries. Although it has attracted a lot of attention in recent years, there is still a lack of research conducting analyses using a comprehensive approach that takes the sports charity into account. The purpose of this paper is to explore the most important factor that affecting the Chinese sports charity. For this purpose System Dynamics is used, because this approach is brilliant at dealing with the complex systems and enables one to capture the critical factor in system. Hence, through the software Vensim 5.4a PLE, this paper constructs the Chinese sports charity system model by the system dynamics method and predicts the future trend covered from 2005 to 2050 in this area by computer simulation. In addition, three experiments further reveal the primary factors affecting sports charity. The results show that strengthening citizen's consciousness of dedication is more efficient than using benefit incentive measures on promoting the development level of sports charity. The paper contributes to a better understanding of sports charity system. Suggestions are made for motivating more people to participate in sports charity.

Keywords Sports charity · System dynamics · Simulation · Sports charitable consciousness

L. Zhang (✉)
School of Business, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: 1010519067@qq.com

J. Hu
Department of Leisure Sports, Chengdu Sport University, Chengdu 610041, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_7

7.1 Introduction

The term sports charity refers to any charitable behavior, motivation and concepts in sports world [18]. Sports social groups and individuals can assist the weak in society, enhance their social reputation, earn tax breaks, obtain psychological satisfaction and enhance their self-efficacy by performing sports charity acts [2, 7, 8]. Then, the leading cause of people engaging in sports charity acts is purely to help others, or to benefit themselves? Some people believed that the sport charity was a social welfare undertaking, and the philanthropist s who was not for material gains kept the view of altruism [4, 22]. While others held the pinion that pure altruism was not enough to explain people's philanthropy [1], and the philanthropists might have a point of egoism.

Altruism refers to the voluntary behavior that good to others without any obvious benefit for behavior subjects. The charitable consciousness is related to the spirit of altruism. A strong charity consciousness makes people more loving and kind in helping the weak in the society. Based on the values of altruism, the primary start point of people engaging in sports charity is to help others, not for their own benefits. Egoism, on the contrary, is regarded as the life attitude and standard of behavior that considering personal benefits prevail over everything. Based on the values of egoism, helping other is just a subordinate effect or a publicity stunt. The main goal is to gain social reputation, to earn tax breaks and to obtain sports lottery winnings. The main significance of this research lies in the fact that to understand if the main reason of people engaging in sports charity activities is altruistic or egoistic, and to find out the key factors that can stimulate people to participate in sports charity.

The development of Chinese sports charity has a long way to go to catch up the steps of that in Europe, the United States and other developed countries. One reason is the lack of charitable consciousness, and another is the imperfection of social mechanism. The main stream of Chinese sports charity is consisted by a small scale group, Olympic champions and world champions, rather than all of the sports stars. "Chinese sports stars seem to be not as keen to philanthropy as foreign ones, not because of lack of love, but lack of consciousness of devotion [3]". For a long time we have been in the background of nationwide system, and implement the strategy for Olympic Glory [10]. For both Chinese athletes and coaches, the greatest return to society and the highest value orientation is to get the Olympic gold medal, which results in athletes and coaches intentionally or unintentionally cutting off the inevitable link between sport and charity. For ordinary people, the lack of charity consciousness, channel, and trust becomes the main reason for the low participation in sports charity [12, 17, 21]. A large part of the funds of sports charity which accumulated by the government from the general public is the sports lottery welfare fund. As is known to all, the majority of Chinese people buy sports lottery for a night of sudden wealth, not for helping others. In order to stimulate people to devote themselves to the sports charity, shall we advocate to raise the sports charitable consciousness, or to establish the interests induced system? If people hold the view of altruism-based, we will take the action of cultivating and strengthening their charitable consciousness of dedication. By contrast, if they hold the concept of egoism-based, we will set up the corresponding interest mechanism to induct.

For the sake of solving above problems, we are going to use the system dynamics method. This theory was proposed by Professor Jay Wright Forrester from MIT in the 1950s. The general steps of system dynamics are: ① To recognize the problem, determine the system boundary, and identify the relevant factors and their causality; ② To draw the causal relationship diagram and the flow diagrams; ③ To compile the DYNAMO equation; ④ To simulate; ⑤ To analyze the result. It is brilliant at dealing with the complex systems, solving the long-term, cyclical, higher-order, nonlinear, and time-varying problems, and also suiting to the scenario analysis and the condition in the absence of data. In a word, it is a kind of methodology to research the socio-economic problem with the combination of quantitative and qualitative analysis. Currently, system dynamics is applied to the field of business management [13, 15, 20], environmental sustainable development [16, 19], social activities [9, 11, 14], and medical and health care [5, 6], which has gained remarkable achievement. But, it is rarely used in analyzing sports problems.

The sports charity is a complex and integral system. Based on the advantages of system dynamics method to analyze the complex systems, we use this method to study the sports charity. The purpose of this research is to explore the most important factor that affecting the Chinese sports charity. Contrary to traditional approaches, this method for analyzing the factors of sports charity is more comprehensive. So we construct the Chinese sports charity system model by this method and predict the future trend covered from 2005 to 2050 in this area through computer simulation. In addition, we perform three experiments for finding out the root cause of people's participation in the sport charity by testing and adjusting the parameters. Hope that through the system dynamics method to provide more scientific ideas for the exploration of sports charity system.

7.2 The System Dynamics Model

7.2.1 Variable Interpretation

There are two core elements of Chinese sports charity system, the sports philanthropist and the sports charity fund, which involved in this study. The fundraising channels of sports charity fund are donation, foundation, sports lottery, auction, sport event and public performance. But only two aspects of them are published by our office: one is the foundations that sponsored and supported by the sports stars (Table 7.1); the other is the public welfare fund from sports lottery. The sports charity fund is mainly used as followed:

Table 7.1 Chinese sports charitable organizations

Institution	Nature	Promoter	Start time	Competent or affiliate organization	Public data
China sports foundation	Government	–	1994	General Administration of China	Web page, Data
China top ten sports champion Laureus foundation	Collective	Deng Yaping and 15 retired world champions and Olympic champions	2005	China Charity Federation	Web page, Data
The Chinese athletes educational foundation	Collective	Ning Li, Zhenhua Cai, Yongbo Li, Haifeng Xu, Yubin Huang, Jihong Zhou, Xiong Ni, Xiaoshuang Li, Rongfang Zhang, Chunyang Li	2001	Hongkong Registration	Web page, No data
Champion foundation	Collective	Yang Yang	2011	Red Cross Society of China	No web page, No data
Yao foundation	Individual	Yao Ming	2011	China Youth Development Foundation	Web page, No data

(1) To support the disabled, needy children and migrant workers' children in education and subsistence;
(2) To support the retired athletes and coaches in educational refreshers and re-employment training;
(3) To support the adolescents in health and physical education;
(4) To aid and build the fitness venues and facilities, and to donate sports fitness equipment for the economic less-developed regions;
(5) To support the national high level sports talented reserve training, the national team preparing for the Olympic Games, and the national comprehensive sports game holding;
(6) To support some special equipment purchasing and maintenance, such as sky-diving, motorcycling, sailing, motor boating and other military sports.

The sports philanthropist group is divided into potential donators and existing donators. When people have a certain charitable consciousness after contacting the sports charity to some extent, they can only be referred as potential donators, because this time they do not donate anything. As time goes on, they will become committed sports charitable donators when some external interests motivate them. Their donations may be one-off or repeated, and they are committed to the life-long sports charity. The hypothetical relationship between the two core variables is very simple. When the number of sports philanthropist increase, the total amount of sports charity fund will increase, and vice versa.

7.2.2 Modeling

(1) Drawing the Causal Relationship Diagram

The causal relationship diagram is a graphic model that qualitatively describes the causal relationship among the elements in the system. It is the foundation of the system dynamics model. Firstly, we try to identify the main elements relating to the two core variables, sports philanthropist and sports charity fund, in the sports charity system. Secondly, we sort out the positive and negative causal relationship among all of the elements. Finally, we use Vensim 5.4a PLE software to draw a causal relationship diagram (Fig. 7.1).

(2) Drawing the Flow Diagram

The flow diagram that based on the causal diagram, further distinguishes the nature of every element, depicts the logical relationship of elements by intuitive symbols, and shows the feedback form and controls the law of the system. The flow diagram provides basis for further research. It is usually consisted by level variable, rate variable, auxiliary variable, parameter, flow, source and sink, information, and delay.

In the flow diagram of Chinese sports charity (Fig. 7.2), the level variables, which reflect the accumulation of material for a period of time, include the potential charitable donator, the existing sports philanthropist, and the total funds of sports charity.

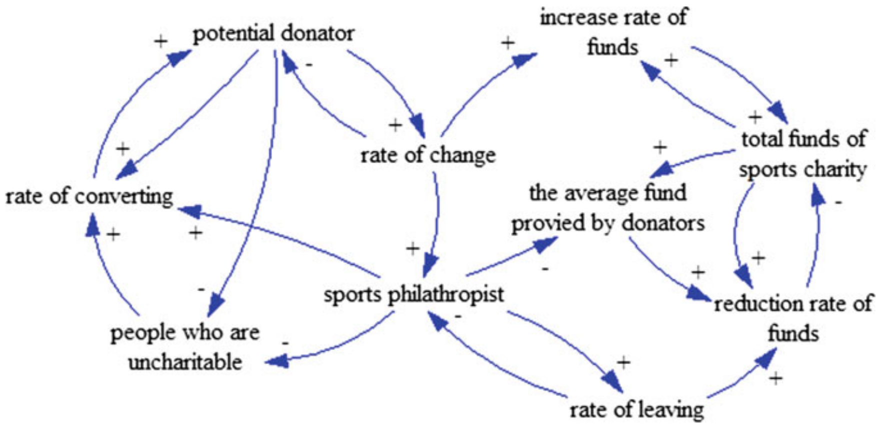


Fig. 7.1 The causal relationship diagram of sports charity system

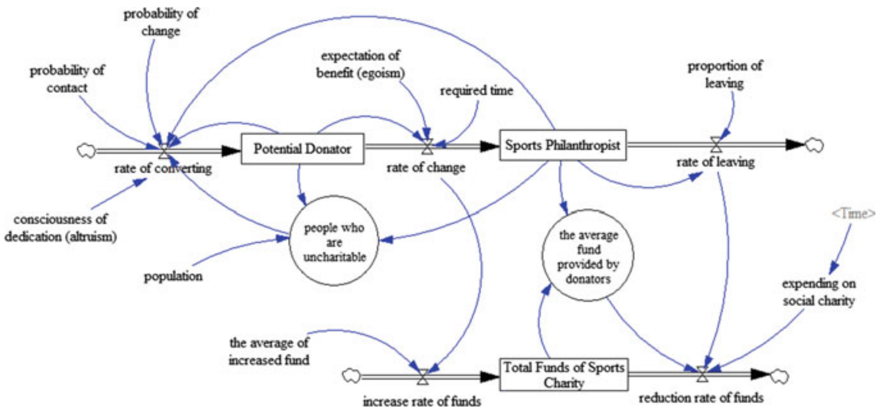


Fig. 7.2 The flow diagram of sports charity system

The rate variables, which reflect the speed and amplitude of level variable change, include the rate of converting from people who are uncharitable to the potential ones, the rate of change from people who are potential to existing, the rate of sports philanthropist leaving, the increase rate of funds from new philanthropists, and the reduction rate of funds for social charity. The auxiliary variable can simplify the expression of the rate variable, which is usually set between the level variable and the rate variable. It includes the people who are uncharitable and the average fund provided by philanthropists. The parameters include the probability of contact of uncharitable people and charitable people, the probability of change of uncharitable people to potential charitable people, the required time of people changing from potential to existing, the proportion of philanthropist leaving, the consciousness of dedication (altruism), the expectation of benefits (egoism), the average of increased fund from new existing charitable people, and the expending on social charity.

(3) Compiling the DYNAMO Equation

DYNAMO (DYNAmic MOdels) is a special language for system dynamics simulation, what we usually use to write the structural equation. The structural equation of system is a set of mathematical relationship based on the flow diagram, and quantitatively describes the relationship among the elements. The principle of DYNAMO Equation is a kind of recursive way that means the next status is decided by the given initial status. And its essence is the differential equation. For computer simulation, the differential equation should be converted into the difference equation. Generally speaking, the DYNAMO Equations are composed by the level equation, the rate equation, the auxiliary equation, the initial value equation and the constant equation. In this study, the 10 major DYNAMO equations concerning the Chinese sports charity system are as followed:

$$\begin{aligned}\text{Potential Philanthropist} = {} & \text{INTEGRAL(rate of converting} - \text{rate of change,}\\ & \text{Potential Philanthropist),}\end{aligned} \tag{7.1}$$

$$\begin{aligned}\text{Sports Philanthropist} = {} & \text{INTEGRAL(rate of change} - \text{rate of leaving,}\\ & \text{Sports Philanthropist),}\end{aligned} \tag{7.2}$$

$$\begin{aligned}\text{Rate of converting} = {} & \text{IF THEN ELSE(consciousness of dedication} > 0,\\ & \text{(Potential Philanthropist} + \text{Sports Philanthropist)}\\ & \text{/(Potential Philanthropist} + \text{Sports Philanthropist}\\ & + \text{people who are uncharitable)} \times \text{people who are}\\ & \text{uncharitable} \times \text{probability of contact} \times \text{probability of}\\ & \text{change, 0),}\end{aligned} \tag{7.3}$$

$$\begin{aligned}\text{Rate of change} = {} & \text{IF THEN ELSE(expectation of benefit} > 0,\\ & \text{Potential Philanthropist/required time, 0),}\end{aligned} \tag{7.4}$$

$$\text{Rate of leaving} = \text{Sports Philanthropist} \times \text{proportion of leaving,} \tag{7.5}$$

$$\begin{aligned}\text{People who are uncharitable} = {} & \text{Population} - \text{Sports Philanthropist}\\ & - \text{Potential Philanthropist,}\end{aligned} \tag{7.6}$$

$$\begin{aligned}\text{Total Funds of Sports Charity} = {} & \text{INTEGRAL(increase rate of funds}\\ & - \text{reduction rate of funds}\\ & \text{Total Funds of Sports Charity),}\end{aligned} \tag{7.7}$$

$$\text{Increase rate of funds} = \text{the average of increased fund} \times \text{rate of change,} \tag{7.8}$$

$$\begin{aligned}\text{Reduction rate of funds} = {} & \text{the average fund provided by philanthropist}\\ & \times \text{rate of leaving} + \text{expending on social charity,}\end{aligned} \tag{7.9}$$

$$\begin{aligned}\text{The average fund provided by philanthropist} = {} & \text{Total Funds of Sports Charity}\\ & \text{/Sports Philanthropist.}\end{aligned} \tag{7.10}$$

Table 7.2 The sports philanthropist and the sports charity fund

Year	The income of sports charity (billion dollar)	The expenditure philanthropist (million dollar)	The number of sports (million people)
2005	1.61	193.01	29.33
2006	1.61	217.55	33.9
2007	1.97	133.54	41.33
2008	2.13	244.93	53.8
2009	2.28	140.91	54.13
2010	2.99	167.45	67.84
2011	3.77	227.93	73.88
2012	4.56	314.79	77.9
2013	5.45	361.17	82.48
2014	7.05	352.49	86.88

(4) Data Selection and Parameter Values Determination

The behavior of sports charity is mainly related to the donation (direct behavior) and the sports lottery purchase (indirect behavior). Hence, the data of both sports philanthropist and sports charity fund involved in this model refers to the range of charitable donation and sports lottery. The relevant data mainly comes from the annual official information about 2005–2014 years (Table 7.2), such as, the Summary of Annual Work Report of China Sports Foundation, the Audit Report of China Charity Federation, the Report of National Lottery Public Welfare Fund Raise and Use, and the Report of Sports Lottery Public Welfare Fund Use from General Administration of China. Taking into account the incomplete data, the collected data used for simulation is through the steps of filtering, comparing and calculating.

In summary, the values of main variables in this model are as followed. 2005 is the starting year. The initial value of potential donator is 6 million people, the initial value of sports philanthropist is 29.33 million people, and the initial value of total funds of sports charity is 193.01 million dollar. Then, the value of probability of contact is 0.4, the value of probability of change is 0.5, the value of altruism is 0.5, the value of egoism is 0.5, the required time is 0.9 year, the proportion of leaving is 6 %, the population is 1.368 billion people, and the average of increased fund from new existing charitable people is 53.26 dollars through analyzing and calculating. The expression of expending on social charity is a table function—WITHLOOKUP (Time (([(2005, 0)–(2050, 500)], (2005, 193.01), (2006, 217.55), (2007, 133.54), (2008, 244.93), (2009, 140.91), (2010, 167.45), (2011, 227.93), (2012, 314.79), (2013, 361.17), (2014, 352.49), (2015, 235.38), . . ., (2050, 235.38)))).

(5) Model Test

Before the simulation, the reliability and stability of the model should be tested. Firstly, the Vensim 5.4a PLE is used to do the Check Unit and the Reality Check. Next, the existing data in terms of sports philanthropist and sports charity fund is

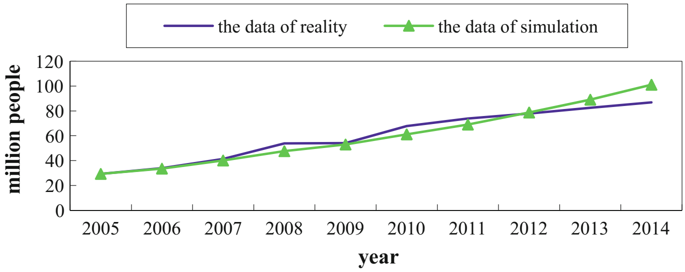


Fig. 7.3 The comparison of simulation data and existing data of sports philanthropist

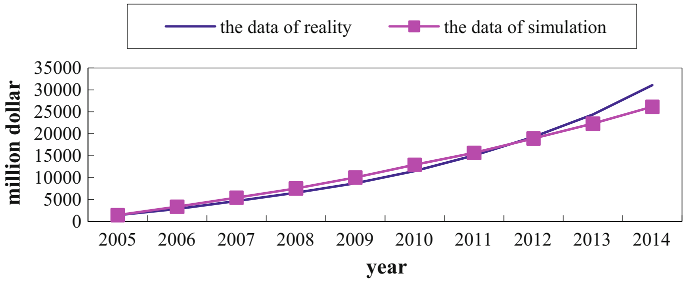


Fig. 7.4 The comparison of simulation data and existing data of sports charity fund

selected to compare with the simulation data from 2005 to 2014 (Figs. 7.3 and 7.4). It shows that the simulation output is basically consistent with the existing data, and the effect is good.

7.3 The Experiments with The Model

7.3.1 Simulation

The scope of simulation time is from 2005 to 2050 (a total of 45 years), and the step is set to 1 year (Fig. 7.5). It is clear to see that the number of sports philanthropist and the total funds of sports charity both show an upward trend. By the end of 2050, the number of sports philanthropist will near 900 million people, and the total funds of sports charity will exceed 283 billion dollar. But the growth rate will gradually slow down after that time. This is a very optimistic and ideal prospect. At the same time, the trend of potential charitable donators will decrease after goes up first, and reaches the peak of 61.56 million people in 2034. Because when people who are uncharitable contact with the charitable ones in the early stage, their consciousness of dedication will be improved, which lead the change rate to be accelerating and the number of potential charitable donators increased. After 2034, the number of

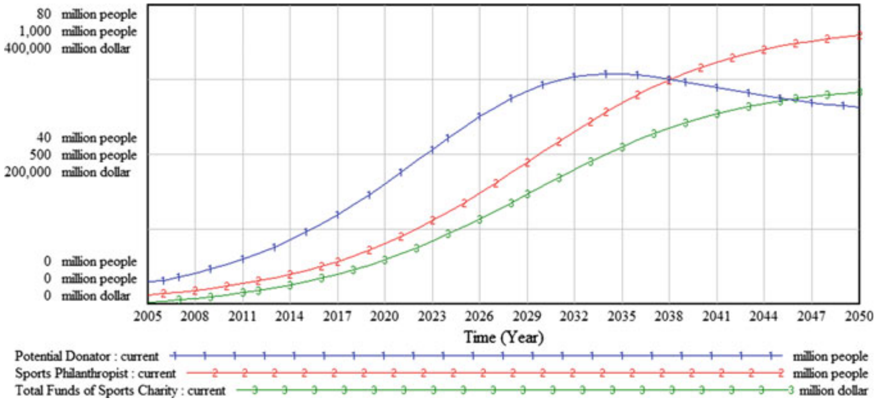


Fig. 7.5 The simulation of potential donator, sports philanthropist and total funds of sports charity

potential charitable donators will begin to decline as a result of the reduction of people who are uncharitable, and the transition of many potential donators into the existing ones. Without doubt, this is just the simulation result that is generated under the established framework and existing data. It can be expected that the average contribution of the new sports philanthropists will increase, and the demand of social charity will reduce, with the improvement of the economic level and the moral level in the future. If that is the case, the total funds of sports charity will maintain rapid growth after 2050.

In the sports charity system, three methods as followed are adopt to make both the number of sports philanthropist and the total funds of sports charity as soon as possible to achieve the expected level. ① To improve the probability of contact between people who are uncharitable and the charitable ones; ② To improve the probability of change from people who are uncharitable to the potential charitable donators; ③ To Shorten the required time when the potential charitable donators become the existing ones. In response, three experiments are used to confirm this.

7.3.2 Experiment 1

When people who are uncharitable contact with the sports philanthropists, their consciousness of dedication (also called the value of altruism) will be improve. So the variable value of the probability of contact is adjusted from 0.4 to 0.5 (Figs. 7.6 and 7.7). It is found that both the rate of converting and the rate of change are accelerating. In the adjusted model, the number of sports philanthropist and the total funds of sports charity in 2034 are able to reach the level of 2050 in the original model.

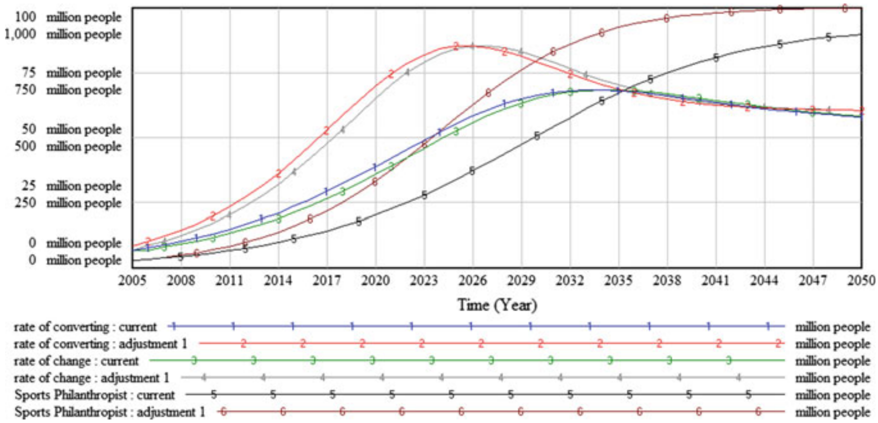


Fig. 7.6 The comparison of current and adjustment 1

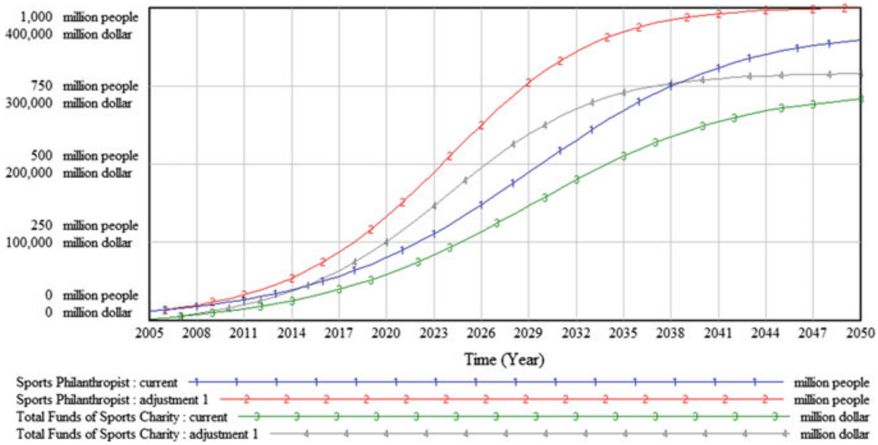


Fig. 7.7 The comparison of current and adjustment 1

7.3.3 Experiment 2

When people's consciousness of dedication is further enhanced on the basis of the original foundation, the rate of converting will accelerate. Thus the variable value of the probability of change is adjusted from 0.5 to 0.6 (Figs. 7.8 and 7.9). In that case, both the rate of converting and the rate of change are accelerating. The number of sports philanthropist and the total funds of sports charity of 2025 in the adjusted model are able to reach the level of 2050 in the original model.

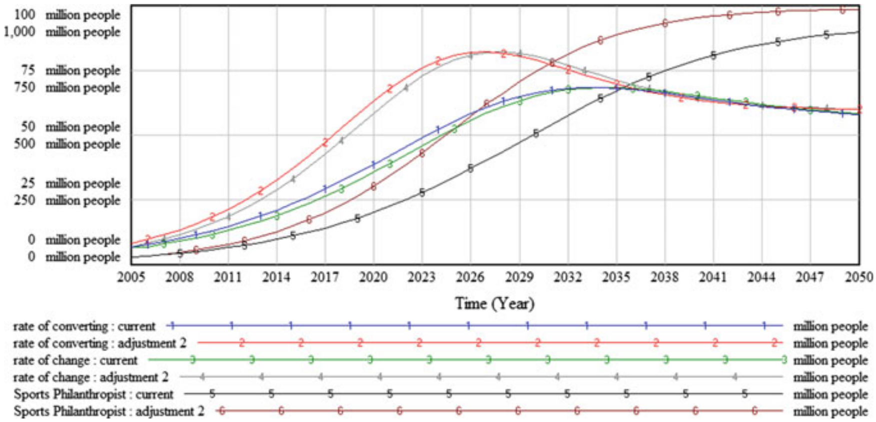


Fig. 7.8 The comparison of current and adjustment 2

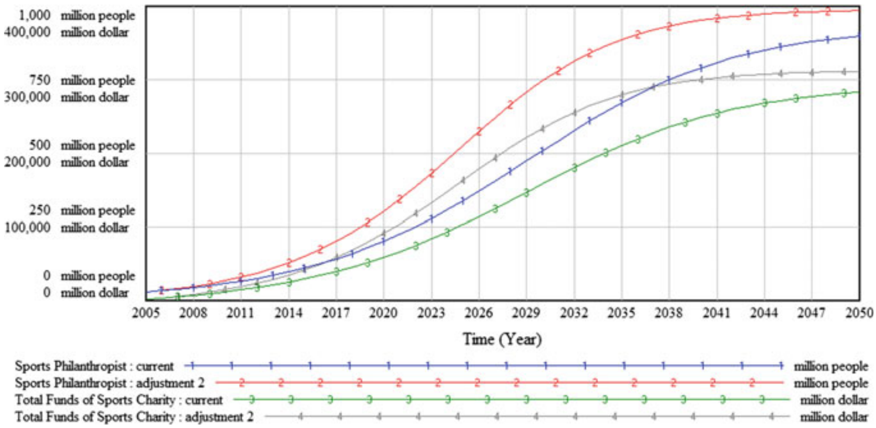


Fig. 7.9 The comparison of current and adjustment 2

7.3.4 Experiment 3

When people's consciousness of dedication maintains at a certain level, the required time will be short by addition of the external benefit incentive (also called the value of egoism). Therefore the variable value of required time is adjusted from 0.9 to 0.8 (Figs. 7.10 and 7.11). As a result, the rate of converting, the rate of change, the number of sports philanthropist, and the total funds of sports charity in the adjusted model have no change, which are compared with the previous ones in the original model.

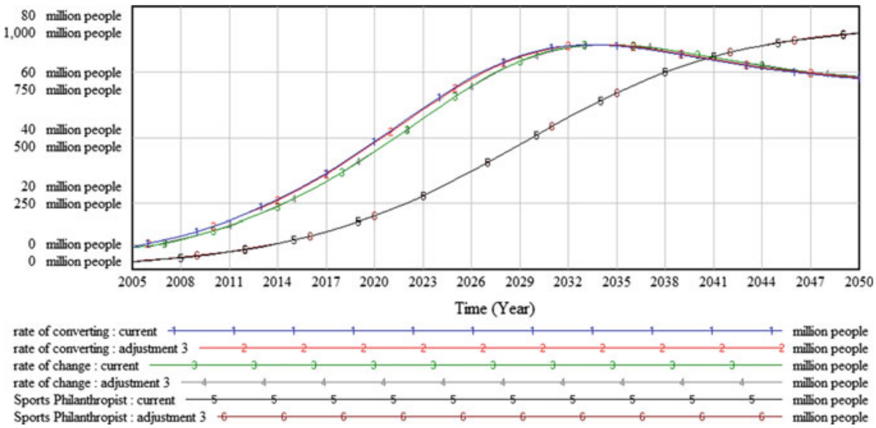


Fig. 7.10 The comparison of current and adjustment 3

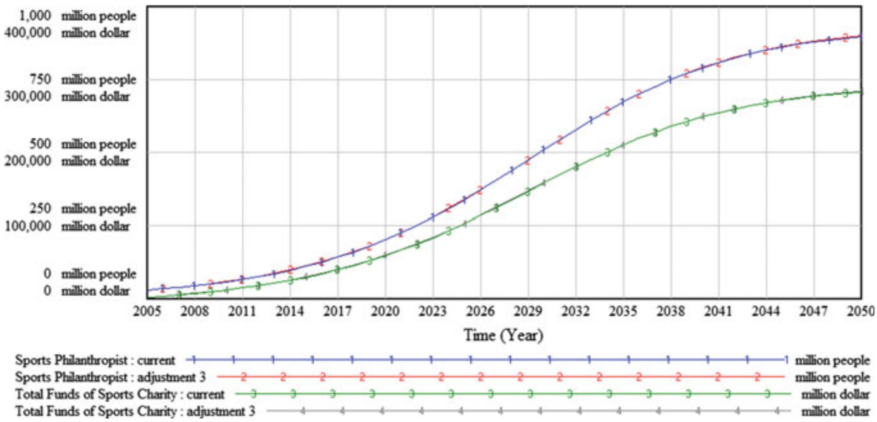


Fig. 7.11 The comparison of current and adjustment 3

7.4 Discussion and Conclusion

In this study, we showed that the number of sports philanthropist and the total funds of sports charity had an upward trend in the next 35 years. There were three ways in theory to reach this level of 2050 in advance (we used three experiments to express respectively). The first experiment was to improve the probability of contact between people who are uncharitable and the charitable ones. The second experiment was to improve the probability of change from people who are uncharitable to the potential charitable donators. And the third experiment was to shorten the required time when the potential donators became the existing ones.

In the experiment 1 and experiment 2, the change of the variables were related to the consciousness of dedication, which meant people's behaviors of sports charity were based on the altruism, and this kind of people preferred to help others. In the experiment 3, the change of the variables were related to the benefit incentive of sports charity, which meant people's behaviors of sports charity were based on the egoism, and this kind of people focused on self-interest. Through simulation, we revealed that the outcome of the experiment 3 was not obvious. To sum up, the most important factor affecting Chinese sports charity was the value of altruism rather than the egoism. Therefore it was important to cultivate and enhance the consciousness of dedication than to take advantage of benefit incentive for increasing the number of sports philanthropist and the total funds of sports charity. Furthermore, to compare with the results of experiment 1 and experiment 2, we also discovered that to adjust the variable of probability of change was more sensitive than to adjust the variable of probability of contact. Consequently, we held the view that to enhance the consciousness of dedication was more effective than to cultivate it for increasing the number of sports philanthropist and the total funds of sports charity.

However the results presented here demonstrated that the consciousness of dedication was very important for sports charity, the consciousness of sports groups and individuals in our country was relatively weak, what was the main reason of dropping behind the other developed countries. In this system dynamics model, the number of sports philanthropist and the total funds of sports charity were considerable, but in fact most of the data came from the indirect behaviors of sports charity (buying sports lottery), instead of the direct donation. The prime motivation of buying sports lottery was to gain profit rather than to help others. As we knew, some sports enterprises and sports stars also pursued self-interest through the sports charity, such as to obtain a good social image, to keep a good relationship with the government, to earn tax breaks and so on. Some people engaged in the sports charity even on account of the external pressure from the media. Thus the behaviors of this kind of sports philanthropists were usually the one-time behavior. The reason of the weak consciousness of dedication was that people lacked of a spirit of altruism in the whole process of sports charity. We put forward that the vigorous propaganda and insightful education were the key to improve consciousness of sports charity, which provided a reference for the related policy design in China.

This paper analyzed the Chinese sports charity system based on the system dynamics theory and method. We predicted the future trend of domestic sports charity by simulation, and found out the main reason affecting the sports charity by adjusting the parameters of three experiments. Further work will be required to perfect the structure of sports charity system, and debug the model to obtain more accurate data.

Acknowledgments We thank Luo Qiufeng for technical assistance; Zhang Xu for help with data collection; Cheng Linlin for guidance. This work was supported by China' National Social Science Fund (Grant #10ATY002).

References

1. Andreoni J (1990) Impure altruism and donations to public goods: a theory of warm-glow giving. Econ J 100(401):464–477
2. Bekkers R, Wiepking P (2010) A literature review of empirical studies of philanthropy: eight mechanisms that drive charitable giving. Nonprofit Volunt Sect Q 40(5):924–973
3. Ci X (2005) China's sports stars only focus on the competition rather than the public welfare. China Youth Daily
4. Crumpler H, Grossman PJ (2008) An experimental test of warm glow giving. J Public Econ 92(5):1011–1021
5. Fallah-Fini S, Rahmandad H et al (2014) Modeling us adult obesity trends: a system dynamics model for estimating energy imbalance gap. Am J Public Health 104(7):1230–1239
6. Figueredo GP, Siebers PO et al (2015) Juxtaposition of system dynamics and agent-based simulation for a case study in immunosenescence. Plos One 10(3):1–17
7. Filo K, Spence K, Sparvero E (2013) Exploring the properties of community among charity sport event participants. Manag Leis 18(3):194–212
8. Filo K, Funk DC, O'Brien D (2014) An empirical investigation of the role of camaraderie, cause, competency, and participation motives in the development of attachment to a charity sport event. Manag Leis 19(4):245–262
9. Gréhaigne JF, Godbout P (2014) Dynamic systems theory and team sport coaching. Quest 66(1):96–116
10. He W, Long Q (2014) Comparative study on the status of sports charity of china and america. J Guangzhou Sports Univ 34:16–19
11. Hou L (2015) System dynamics simulation of large-scale generation system for designing wind power policy in China. Discrete Dynamics in Nature and Society pp 1–11
12. Huang S (2007) Problems and countermeasures in the development of china's sports charity. Sports Culture Guide pp 56–58
13. Lehr CB, Thun JH, Milling PM (2013) From waste to value-a system dynamics model for strategic decision-making in closed-loop supply chains. Int J Prod Res 51(13):4105–4116
14. Macmillan A, Connor J et al (2014) The societal costs and benefits of commuter bicycling: simulating the effects of specific policies using system dynamics modeling. Environ Health Perspect 122(4):335–344
15. Mula J, Campuzano-Bolarin F et al (2013) A system dynamics model for the supply chain procurement transport problem: comparing spreadsheets, fuzzy programming and simulation approaches. Int J Prod Res 51(13):4087–4104
16. Nyerges T, Roderick M et al (2014) Foundations of sustainability information representation theory: spatial-temporal dynamics of sustainable systems. Int J Geogr Inf Sci 28(5):1165–1185
17. Pan S (2010) Countermeasures to the issues in the development of China's sports charity. J Beijing Sport Univ 33:30–33
18. Qiang Z (2007) Preliminary study of sports charity. J Phys Educ 2:141–144
19. Song J, Xiang B et al (2014) Application of dynamic data driven application system in environmental science. Environ Rev 22(3):287–297

20. Taki E, Mirghafoori HA, Sharifabadi AM (2015) Analysis of the factors affecting customer satisfaction: Customer relationship management approach using system dynamics model. Int J Acad Res 7(1):579–584
21. Xiang L (2011) On difficulty and choices confronting development of sports charities in China. J Xi'an Phys Educ Univ 28:318–321
22. Zhou Y, Fang C (2011) The psychosocial function of sports charity. J Jilin Inst Phys Educ 92(27):32–33

Chapter 8
Research About Construction of Public Service Capacity of Safety Production Evaluation Indication System and Evaluation Method

Yu Liu, Chao Chen, Xu Shao, Xinsen Qian and Zhaohui Zhang

Abstract In this paper, from the capacity of government safety regulation and public oversight, legal protection capacity, capability of technical equipment support, capacity of accident prevention and comprehensive governance, capacity of accident rescue and emergency response, capacity of public safety awareness and self-help and mutual rescue, the author attempts to establish the evaluation index system on public service capacity of the safety production, with combination of the development in Chengdu, by means of scientific decision-making thought of AHP and Delphi. Then the author elaborated the research method about the basic principles and thinking, numerical standardization, Weight assignment and so on. Finally, the author tried to build a complete evaluation index system on public service capacity of the safety production, taking Chengdu for empirical research.

Keywords The public service capacity of safety production · Evaluation index system · Analytic hierarchy process

8.1 Introduction

The fundamental purpose of safety production aimed at preventing and reducing of accidents, protecting of people's lives, health and property. As a technology business center in southwest, Chengdu had a 10056.6 billion GDP in 2014, ranking the fourth sub-provincial city. With the rapid industrialization and urbanization progress, safety hazards were also highly aggregated in Chengdu, leading to negative social effects of production accident multiplied. It is shown that the safety conditions in Chengdu had significantly improved in recent years, and the number of accidents, casualties, economic losses showed a steady downward trend year by year. But the total on the production safety accident is still large, and the traditional industries of construction,

Y. Liu · C. Chen (✉) · X. Shao · X. Qian · Z. Zhang
School of Political Science and Public Administration of UESTC,
Chengdu 611731, People's Republic of China
e-mail: minnesotacc@126.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_8

transportation, fire and other accidents remain high. To this situation, to enhance the public service capacity of safety production, including government regulatory, social security organizations, guiding public opinion, and capacity of public security, which make economy and society more stable and healthy on the safety production is desiderated. Therefore, it is necessary to build a scientific evaluation system about public service capacity of safety production. It can quantify public service capacity of safety production in Chengdu. As a result, it produces a more comprehensive and thorough assessment. So managers can easily recognize their own potential and shortcomings, find out the main directions, then pursuing objectives on the basis of past experience, to promote public services capacity of safety production for the government.

8.2 The Basic Principles of Indicator System

8.2.1 The Combination of Dynamics and Association

The dynamics are that various factors are interrelated and motive development on the management activities, which are mutual influence and restraint. This principle shows on the process of safety production public service capacity, their capacities restrict not only by their own conditions, but also mutual influence, limitations and other relevant factors with the change of phase and location. Therefore, we should pay attention to the dynamics development of the various factors, grasping the relevant dynamics characteristics of all production-related factors, then making it faster.

8.2.2 The Combination of Quantitative Analysis and Qualitative Analysis

Qualitative analysis is to reveal rules of thing running or the phenomenon, and then to make basic judgments from its basic situation. Quantitative analysis can quantify the results of qualitative analysis, and make more precise determinations [2]. It can choose quantifiable indicators as much as possible when building evaluation index system on the public service capacity of the safety production in Chengdu. To difficult quantitative indicators, it should be the quantitative conversion before using qualitative indicators to describe it.

8.2.3 The Combination of Scientificalness and Feasibility

The scientific and rational structure of index system is directly related to quality of comprehensive evaluation and practical effect [4]. So building evaluation index system on the public service capacity of the safety production in Chengdu should be on the basis of scientific analysis. On the one hand, it should fully consider general goals and total requirements of it. On the other hand, it should build the index system on the base of using rationally scientific theory, and taking the strong operability of index system about data acquisition and statistics into account. Evaluation index should be simple, practical, quantifiable, clear and easy collecting [1].

8.2.4 The Combination of Systematicness and Representativeness

The public services capacity on safety production, it is related to many aspects like safety regulation, emergency rescue, policies and regulations, safety information, which is a complex system. When building evaluation index system, it fully considers the completeness and representativeness. Especially, it should not only be simple and clear to improve and perfect the evaluation system, but also comprehensively reflecting every factors of the capacity of public services on safety production.

8.3 The Ideas of Building Index System

The public services capacity on safety production is that the government as the main part of public organizations, according to reality of economy social development and requirement of the public, provide information security products and services that public safety infrastructure, safety supervision, safety emergency rescue, safety regulations and standards policy and security information for production-operation units and the public on the production operation activities and other activities like safety production, health and safety management.

The public services capacity on safety production covers a wide range. So that it has different definitions and requirements on the different countries and regions. According to requirements of national security strategic planning and the provincial government for basic capacity building on the safety production, through the multi-disciplinary knowledge like management, statistics and mathematics, we think that the public services capacity on safety production consist of "six capabilities". It be based on the extensive literature analysis and field research, through the correlative theory of evaluation index system on the public services capacity on safety production. Namely, six capabilities have capacity of government safety regulation and public oversight, legal protection capacity, capability of technical equipment support, capacity of accident prevention and comprehensive governance, capacity of accident rescue and emergency response, capacity of public safety awareness and self-help and mutual rescue.

8.4 The Constitution of Index System

8.4.1 Capacity of Government Safety Regulation and Public Oversight (*A*1)

The capacity of government safety regulation and public oversight consists of three sub-systems and ten indicators.

(1) Organization Security ($B1$)

Leadership attention ($C1$), it mainly investigates situation that the leaders inspect the work and conference of production safety; Responsibility system implementation ($C2$), it mainly investigates establishment and implementation of specific responsibilities on the party and government departments, even the signing of book on the production safety responsibility. Agency and staffing ($C3$), it mainly investigates installment and allocation of agency and staffing on the safety supervision. Team building ($C4$), it mainly investigates inspectors on the certificates rate and regular training situation; Funding security ($C5$), it mainly investigates budget and financial budget on the special fund, even its efficiency.

(2) Administrative Supervision ($B2$)

Percentage of coverage on the supervision and inspection ($C6$), it mainly investigates coverage ratio of supervision and inspection on the safety supervision agencies and departments for production units; Efficacy of supervision and inspection ($C7$), it mainly investigates whether blank and cross-cutting areas exist on the supervision and inspection on the safety production.

(3) The Social Monitoring ($B3$)

Public report ($C8$), it mainly investigates check rates and verified rate of information from public report; Industry self-restraint ($C9$), it mainly investigates establishment situation of industry association and establish conditions of restraint mechanism on the safety production; Media monitoring ($C10$), it mainly investigates the municipal media active exposure on the safety hazards.

8.4.2 Legal Support Capability (*A*2)

Legal support capability consists of two sub-systems and six indicators.

(1) Construction of Legal System ($B4$)

Laws and regulations ($C11$), it mainly investigates perfection degree of comprehensive regulations on the safety production, special regulations and government regulations; Standard rules ($C12$), it mainly investigates whether or not it has an access conditions for the city's industry, safety technology standards and management standards.

(2) Enforcement Capacity ($B5$)

"Three simultaneousness" coverage of safety production ($C13$), it mainly investigates coverage ratio on the various projects complying with "three simultaneousness" on the process; The fine collection rate ($C14$), it mainly investigates penalty proportion of safety production accidents; Periodical clearance rate ($C15$), it mainly investigates the ratio of regular clearance number in investigation accident totality; Administrative enforcement misjudged case rate ($C16$), it mainly investigates proportion of cases about hold the administration in all enforcement cases.

8.4.3 Technology and Equipment Support Capabilities (*A*3)

Technology and equipment support capabilities consists of three sub-systems and four indicators: Infrastructure ($B6$), it mainly investigates situation of using room on the work, business and security services ($C17$); Equipping ($B7$), it mainly investigates whether it had necessary equipment of adapt dynamic supervision and emergency rescue ($C18$); Information construction ($B8$), it mainly investigates whether it had a good network of information exchange and open government platform ($C19$); Whether it had established information technology systems on the eight major business applications, and timely updating and inspection about database ($C20$).

8.4.4 The Capabilities of Accident Prevention and Comprehensive Management (*A*4)

Accident prevention and comprehensive management capabilities consists of three sub-systems and ten indicators.

(1) Security Incident Control ($B9$)

The proportion of overall control indicator ($C21$), it mainly investigates proportion of accident deaths number in the total number of fatalities for the annual control indicators; A greater proportion of more accidents control targets ($C22$), it mainly investigates proportion of number about fatal accident in the total number of the accident that annual control deaths indicators; the proportion of traffic accident control indicator ($C23$), it mainly investigates proportion of traffic accident death toll in the total number of the accident that annual control deaths indicators; The proportion of industrial and commercial trade accident control indicator ($C24$), it mainly investigates proportion of fatalities on the industrial and commercial trade accident in the total number of the accident that annual control deaths indicators.

(2) Hidden Danger Investigation and Control ($B10$)

Hidden trouble rectification ratio ($C25$), it mainly investigates proportion of rectification cases of the safety production hidden trouble in cases of annual supervision and inspection; Major hidden rectification ratio ($C26$), it mainly investigates proportion of major safety hazard rectification cases in cases of annual supervision and inspection; Occupational hazard program reporting rate ($C27$), it mainly investigates proportion of reporting cases of occupational hazard programs in cases of safety production programs; Hazard factor detection rate of occupational disease ($C28$), it mainly investigates proportion of detection cases of occupational disease hazard factor in total detection.

(3) Production Safety Infrastructure ($B11$)

Safe community building rate ($C29$), it mainly investigates proportion of safe community quantity in all communities; Corporate safety standardization compliance rate ($C30$), it mainly investigates proportion of corporate safety standardization quantity in all corporates.

8.4.5 Accident Rescue and Emergency Response Capabilities (A5)

Accident rescue and emergency response capabilities consist of four sub-systems and four indicators: emergency Organization system ($B12$), it mainly investigates whether it has adequate emergency response organization and staffing ($C31$); Emergency rescue plan ($B13$), it mainly investigates whether it has the perfect emergency Rescue Plan ($C32$); Emergency information database construction ($B14$), it mainly investigates whether it has emergency rescue consultants, rescue teams and rescue personnel information base ($C33$); Emergency rescue drill ($B15$), it mainly investigate whether it organized professional accident rescue exercise ($C34$).

8.4.6 Public Safety Awareness and Self-help and Mutual Aid Capabilities (A6)

Public safety awareness and self-help and mutual aid capability consists of three sub-systems and three indicators: safety education and training ($B16$), it mainly investigates perfect degree of safety production training systems on the municipal authorities at all levels and training rate of industry practitioners ($C35$); Safety culture construction ($B17$), it mainly investigates situation of the law popularization on the safety production; Public safety awareness ($B18$), it mainly investigates public safety precaution and self-help and mutual aid capability ($C37$).

8.5 Evaluation Methods

8.5.1 Numerical Standardization

On the evaluation system of safety production public service capacity, source data dimension of different index and order of magnitude are different. So those unit and variation degrees are also different. In order to avoiding explaining difficulty for disunity of unit, it is necessary to standardize source data to numerical value.

For the forward index, the common numerical methods are linear and nonlinear [6]. In order to facilitate processing data later, we chose standard deviation to unify data mapping into [0, 1]. The calculation formula is as follows:

$$y_{ij} = \frac{x_{ij} - \min\{x_j\}}{\max\{x_j\} - \min\{x_j\}}.$$

In the calculation formula, i indicates the number of evaluation module, and j indicates the number of evaluation indicators. x_{ij} indicates standard score of the I on the evaluation module and J on the evaluation indicators.

For the reverse index, it is necessary to reverse the process, and the calculation formula is as follows:

$$y_{ij} = \frac{\max\{x_j\} - x_{ij}}{\max\{x_j\} - \min\{x_j\}}.$$

According to the standard score and weight value of the index, after obtaining the standard score of each index, it will make comprehensive evaluation to safety production public service capacity with weighted and module. Module layer, subsystem layer and comprehensive evaluation method of safety production public service capacity are as follows:

$$A_i = \sum_{\mathrm{j=1}}^{\mathrm{m}} B_{ij},$$

$$B_{ij} = \sum_{\mathrm{k=1}}^{\mathrm{n}} y_{ijk} w_{ijk},$$

$$F = \sum_{\mathrm{i=1}}^{1} A_i.$$

In the calculation formula, y_{ij} indicates standardized score of the i^{th} in the evaluation module. w_{ijk} indicates weight value of the index. B_{ij} indicates the evaluation score of i^{th} module and j^{th} sub-system. A_i indicates evaluation score of i^{th} module on the safety production public service capacity. F indicates comprehensive evaluation score of safety production public service capacity.

8.5.2 Weight Determination

The weights determination should aren't only reflection of objective information, but also the policy makers of subjective judgment [7]. It is difficult to obtain the sample data. In order to the importance index of each factor being objective and effective, it is supposed to adopt Delphi method and analytic hierarchy process when evaluating the weight of indexes systems. Delphi method can break through limiting of qualitative analysis on the traditional method. So it will provide a more widen thinking for making rationally decision [5]. The analytic hierarchy process, the method of decomposition on the related elements, On the basis of analysis, it is systematic, flexible and simple [3]. In this paper, we obtained scores of subjective data from the open-ended questionnaire on the 10 experts of production areas, 50 staff in Chengdu Safety Supervision Bureau and the public. The questionnaires and valid questionnaires were 100 %.

(1) It established a hierarchical structure model. Namely, it has the target layer (Safety Production Public Service Capacity in Chengdu), the module layer (A layer), the subsystem layer (B layer), and the index layer (C layer).

(2) It constructed judgment matrix with compared all of the 3 databases with each other. Then it used the 1–9 scale (Table 8.1) on the base of expert consultation, to compare with all importance of the 3 databases with each other on the different modules, subsystems and different indexes.

(3) Single sequence and consistency were checked. For the judgment matrix B, firstly it must meet for eigenvalues and eigenvectors of $BW = \lambda \max W$. Namely, $\lambda \max$ is the maximum eigenvalues of judgment matrix B. W is normalized feature vector of corresponding. W has weight W_{ij} that is weight value of each subsystem on the corresponding index system and index. Then it calculates the consistency ratio through formula $C.R. = C.I./R.R.$ and test the judgment matrix. When $C.R.$ being less than 0.10, the consistency of the judgment matrix can be accepted, otherwise the judgment matrix is modified [4]. The $C.I.$ is the consistency index of the judgment matrix and $R.I.$ is the consistency index of average random.

(4) Hierarchical aggregate ranking and consistency were checked. After calculating the relative importance of each level index, we should carry on the level of

Table 8.1 Definition of judgment matrix

Scale a_{ij}	Definition
1	a_i and a_j are equally important
3	a_i is slightly more important than a_j
5	a_i is rather important than a_j
7	a_i is significantly more important than a_j
9	a_i is more important than a_j
2, 4, 6, 8	The middle degree of the adjacent
Count backwards	The importance of the ratio of the two factors is $a_{ij} = 1/a_{ij}$

Table 8.2 Safety production public service capacity evaluation indication system in Chengdu

Target layer	Module layer	Weigh score	Subsystem	Weigh score	Evaluating indicator	Weigh score
Public service capacity of safety production	$A1$	30	$B1$	13	$C1$	2
					$C2$	3
					$C3$	3
					$C4$	2
					$C5$	3
			$B2$	8	$C6$	5
					$C7$	3
			$B3$	9	$C8$	3
					$C9$	3
					$C10$	3
		18	$B4$	6	$C11$	3.5
	$A2$				$C12$	2.5
			$B5$	12	$C13$	3
					$C14$	3
					$C15$	3
					$C16$	3
	$A3$	10	$B6$	1.5	$C17$	3.5
			$B7$	2.5	$C18$	2.5
			$B8$	6	$C19$	3
					$C20$	3
	$A4$	25	$B9$	11	$C21$	3
					$C22$	3
					$C23$	1.5
					$C24$	2.5
			$B10$	10	$C25$	2
					$C26$	4
					$C27$	3
					$C28$	3
			$B11$	4	$C29$	2.5
					$C30$	2.5
	$A5$	8	$B12$	2	$C31$	3
			$B13$	2	$C32$	3
			$B14$	2	$C33$	2
			$B15$	2	$C34$	2
	$A6$	9	$B16$	3	$C35$	2
			$B17$	3	$C36$	2
			$B18$	3	$C37$	2

the overall ranking, calculating the synthetic weight of the total target, testing the consistency. It would obtain the weight coefficients of each index after processing data from the above method. Taking into account the operability, it was 100 to the sum of weights of all indicators. So it could get weight of each index after weight of indicators multiply upper total value of index weight.

The concrete results were showed in Table 8.2.

8.5.3 Evaluation Results and Analysis

In this paper, its evaluation would take percentile on Chengdu public service capacity of safe production. According to the evaluation index score, it divided into four grades, “excellent” (100-90), “good” (89-80), “qualified” (79-60) and “unqualified” (59-0). According to previous standardized data and weights, taking Excel software as a statistical tool and formula $Y = \sum_{i=1}^{n} W_i X_i$ (W_i as the weight of index, X_i as the standard value of each index), its comprehensive evaluation of public service capacity of safety production in Chengdu was 68 points by calculated the. Its level was qualified and still in a more general level, many places for improvement.

It was different the actual score. To ranking of each dimension capacity, it excluded the weights affect to get percentile scoring. As a result, it was the objective ranking. Specific results were shown in Table 8.3.

It is shown on the Table 8.3, capacity of public safety awareness and self-help and mutual aid in the “good” rating. Percentile score was between 82–83 points. So it should remain it going in Chengdu. The capacity of government safety regulation and public oversight, the capacity of legal protection, the capacity of accident prevention and comprehensive governance, accident rescue and emergency response, they were still in qualified rating. Percentile scores were between 68–69 points. So it should strengthen them in Chengdu. The capacity of technical equipment support was in unqualified rating. The percentile score was only 35 points. So it need greatly improved it in Chengdu, in order to better the development of safe production.

Table 8.3 Score and ranking on evaluation index of public service capacity of safety production in Chengdu

Psublic service capacity of safety production	Excellent	Good	Qualified	Unqualified	Percentile scoring	Actual score	Ranking
$A1$			√		71	21.31	3
$A2$			√		68	12.2	5
$A3$				√	35	3.5	6
$A4$			√		72	17.89	2
$A5$			√		70	5.66	4
$A6$		√			83	7.5	1

8.6 Conclusions

It can meet the safety needs of the production business units and the people's growing, protect the people's lives and property and health only effectively improving the level of public service. At present, there are many researches and research results on the government responsibility in the field of safety production in China. However, the research on safety production public service capacity is not enough. The research on evaluation of safety production public service capacity is less, even other evaluation is still blank. So it is urgent to discuss and solve the major issue that how to measure comprehensively and evaluate systematically on the safety production public service capacity. In this paper, taking Chengdu as an empirical study, the discussion and construction of safety production public service could provide a reference for governments at all levels and relevant departments, also tries to break the ice to intensive study of the academic study.

Acknowledgments This study is funded by the Soft Science Project of Chengdu (2015-RK00-00009-ZF).

References

1. Li K, Jia Y (2005) Fuzzy comprehensive evaluation for full-text periodical databases based on ahp. Inf Sci 11:1688–1691
2. Lin S, Li H (2011) Introduction to the nonlinear systematics in safety production. 3, Sichuan Science and Technology Press, Chengdu
3. Xue D, Jiaming L et al (2012) Research on computation methods of AHP wight vector and its applications. Math Prac Theory 42(7):93–100
4. Yang D, Yang X (2001) A method of quantitative evaluating of regional sustainable development and its application. J Northwest Norm Univ (Nat Sci) 37(1):85 (in Chinese)
5. Yang Z, Wu Y, Yuan D (1995) A quantitative discussion on Delphi. Inf Stud: Theory Appl 5:11–13
6. Yu L, Pan Y, Wu Y (2009) Research on data normalization methods in multi-attribute evaluation. Libr Inf Serv 53(53):136–139
7. Zhang B (1999) A new method for determining weights. J Ind Eng Manag 3:73–74

Chapter 9
Hotelling Model Based Dynamic Pricing of Three Sides

Xiaoyang Zhou, Canhui Zhao, Hui Li and Yan Tu

Abstract In this paper, we introduce the third firm into the original market, and continue to analyze the pricing game of three and the equilibrium of dynamic pricing that three firms achieve. We choose to set the case into a pricing game in the expanding Hotelling model. Through the analysis and comparison, we conclude that firms which implement dynamic pricing based on price discrimination will be better off than those not. In addition, we can reach a crucial conclusion that the firm which embraces a strong power of monopoly advantage and charges a higher price in the duopoly market is sure to make more profits through dynamic pricing based on price discrimination no matter in duopoly market or where added the third side, while other firms will make less profit in the pricing game undoubtedly.

Keywords Dynamic pricing · Duopoly · Three sides · Hotelling model · Price discrimination

9.1 Introduction

Trace back to 18 century, scholars in western academic circle have been starting to focus on game and decision. "Game Theory and Economic Behaviors" [24] published by Neumann and Morgenstern marked that systemic game theory came into being. In recent decades, Game Theory has been applied widely in many fields, especially in revealing the mutual conditionality of economic behaviors.

Three winners of 1994 Nobel Prize in Economics, John C. Harsanyi, John Forbes Nash Jr. and Reinhard Selten introduced a lot of mathematical models

X. Zhou · C. Zhao · H. Li
International Business School, Shaanxi Normal University, Xi'an 710062, People's Republic of China

Y. Tu (✉)
School of Management, Wuhan University of Technology, Wuhan 430070, People's Republic of China
e-mail: tuyan_belle@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_9

to analyze products' pricing from the perspective of Game Theory, which initiated new thoughts and approaches to products' pricing.

We commonly intend to solve for Nash equilibrium to research duopoly model through Cournot model, Stacklberg model, Hotelling model, Bertrand model, etc. Narasimhan [17] considered the pricing mechanism in the situation of existing the price expectation. Due to the interaction between the decisions of retailers and the behavior of consumers, papers all involve rational expectations equilibrium (REE) between retailers and consumers.

Oligopoly was first introduced by Cournot, whose model was considered as the basis of duopoly model. In a typical Cournot oligopoly, there are two players, no other players can enter the market, and collusive behavior is prohibited. Each player in the oligopoly market aims to maximize its expected profit, and profit is maximized when marginal revenue is equal to marginal cost [8]. Bertrand duopoly model solves the problem of two firms' competitive pricing through Nash equilibrium in duopoly market. Stacklberg duopoly model analyzes the best solution of Nash equilibrium of company pricing in duopoly market under the situation of second-mover advantage. The principle of minimum differentiation introduced by Hotelling [11] represented a starting point in the theory of optimal location. When two firms selling a homogeneous product with constant marginal cost of production are situated along a linear market, the firms will locate as close to each other as possible. If, furthermore, consumers are distributed uniformly along the market line then the firms will locate in the center of the market. The reason is the desire of the firm to gain as much hinterland as possible; if one of the firms locates away from the center it will get a smaller share of the fixed market [2].

Kats [12] studied the model where the linear space was replaced by a one-dimensional bounded space without a boundary, i.e. a circle. It was shown that the modified Hotelling model had a subgame perfect equilibrium in pure strategies and that the "equal distance" location pattern was an equilibrium. Balvers [2] proposed that reducing the distance to the other firm raised expected demand and payoff but also lowered the degree of differentiation between the firms, thus raising demand uncertainty in Hotelling model. Fleckinger and Lafay [9] discussed the nature of competition depending on the relative flexibility of products and prices in Hotelling's duopoly. Anita van den Berg, Iwan Bos, Herings and Peters [23] studied a dynamic Cournot duopoly in which suppliers had a limited amount of products available for two consecutive periods. They derived optimal sales strategies and analyzed welfare effects with and without commitment. Elsadany [8] pointed out in the literature on oligopoly games, most papers focused on games with homogeneous strategies, namely, players adopted the same expectation rule and another branch of the literature made up of studies in which games with different strategies should be taken into consideration. Raju, Srinivasan, and Lal [19] investigated the effect of brand loyalty on retailers' price cutting strategies. Bester and Petrakis [4] pointed out that retailers could implement pricing discrimination targeted at consumers with different organizations of information through price cutting strategies. Anderson [1] studied a price leadership configuration: the firms chose the locations sequentially, then a Stackelberg price competition took place. His aim was to determine which firm chose to be the price leader. Osborne and Pitchik [18] characterized the subgame perfect location-price equilibrium in Hotelling model of spatial competition.

However, a pricing game of three sides which a new one joining in duopoly has been little discussed till now. It is also meaningful in our social practice. Duopoly or companies that want to join in the market where duopoly has existed will all be enlightened. In fact, it is interesting to study a game of three in many different fields. Therefore, this paper try to analysis the pricing game among three firms [15].

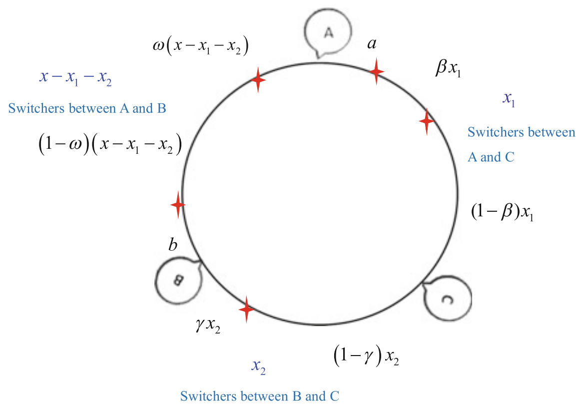
9.2 Pricing Game of Three Firms

We take the situation into consideration that Firm C joins the market where originally the duopoly, respectively Firm A and Firm B existed. It is widely existed in the practice after all. Firm C will try its best to grab the market share from Firm A and Firm B by charging a lower price. What results will happen to the three firms through a pricing game. Let's continue our further discussion based on reconstructive Hotelling model. See the Fig. 9.1.

We set up a circle Hotelling model which develops from the original one in [15].

Consider a market where three firms, denoted respectively as Firm A, Firm B and Firm C, locate at the circle in the illustration. We assume that each has a constant cost, which we set to equally and the three firms play a two-period game for simplicity. All consumers and firms are risk neutral in our model. There are three segments of consumers in this market. The first two segments consist of those consumers who are loyal to, respectively, Firm A and Firm B, and these two loyal segments have the size of, respectively, a and b. As a new member of the market, Firm C has no loyal consumers so that it will grab as more switchers from Firm A and Firm B as possible. We will still restrict the conditions of reserving the loyal consumers for Firm A and Firm B like the discussion of part 3 above. In addition, the third segment of consumers consists of switchers with the size of x, including three segments,

Fig. 9.1 Hotelling circle model of three sides



denoted respectively as x_1 which between A and C, x_2 which between C and B, and $x - x_1 - x_2$ which between B and A. We normalize the total market size to 1 so that we have $a + b + x = 1$. We show the specific distribution in the illustration above.

Define p_i^T as Firm i's price in period T, c_i as switchers'purchase cost targeted at the three firms, π_i^T as Firm i's profit function in period T, where $i = A, B, C$ and $T = 1, 2$.

9.2.1 Pricing Game of Three Firms in the First Period

We assume $p_A^1 > p_B^1 > p_C^1$ in our case.

For Firm A, if it intends to reserve its own loyal segments, it will be bound to have

$$\begin{cases} p_A^1 < p_C^1 + tx_1, \\ p_A^1 > p_C^1. \end{cases}$$

In summary, $p_C^1 < p_A^1 < p_C^1 + tx_1$, according to the bargain solution of Nash equilibrium, we must have

$$p_A^1 = p_C^1 + \frac{1}{2}tx_1. \tag{9.1}$$

In the meantime,

$$\begin{cases} p_A^1 < p_B^1 + t\left(x - x_1 - x_2\right), \\ p_A^1 > p_B^1. \end{cases}$$

In summary, $p_B^1 < p_A^1 < p_B^1 + t\left(x - x_1 - x_2\right)$, according to the bargain solution of Nash equilibrium, we must have

$$p_A^1 = p_B^1 + \frac{1}{2}t\left(x - x_1 - x_2\right). \tag{9.2}$$

For Firm B, if it intends to reserve its own loyal segments, it will be bound to have

$$\begin{cases} p_B^1 < p_A^1 + t\left(x - x_1 - x_2\right), \\ p_B^1 < p_A^1. \end{cases}$$

It is obvious that this condition comes into existence all the time. In addition,

$$\begin{cases} p_B^1 < p_C^1 + tx_2, \\ p_B^1 > p_C^1. \end{cases}$$

In summary, $p_C^1 < p_B^1 < p_C^1 + tx_2$, according to the bargain solution of Nash equilibrium, we must have

$$p_B^1 = p_C^1 + \frac{1}{2}tx_2. \tag{9.3}$$

Combine Eqs. (9.1) and (9.2), we have

$$p_C^1 + \frac{1}{2}tx_1 = p_B^1 + \frac{1}{2}t\left(x - x_1 - x_2\right). \tag{9.4}$$

Substitute p_B^1 from Eqs. (9.3) into (9.4), we have

$$x_1 = \frac{1}{2}x. \tag{9.5}$$

In addition, in order to take up more market share of switchers, Firm B is bound to locate close to Firm C and far from Firm A, namely, $x - x_1 - x_2 > x_2$, i.e. $x_2 < \frac{1}{2}x_1 = \frac{1}{4}x$.

We can readily formulate the purchase cost of switchers from x_1 between A and D targeted at the two firms,

$$c_A = p_A^1 + \beta x_1 t,\ c_C = p_C^1 + (1 - \beta)\, x_1 t.$$

According to the definition of Nash equilibrium, we have

$$c_A^* = c_C^*.$$

Hence, we have $\beta = \frac{1}{4}$, $1 - \beta = \frac{3}{4}$.

Then we can readily formulate the purchase cost of switchers from between C and B targeted at the two firms,

$$c_B = p_B^1 + \gamma t x_2,\ c_C = p_C^1 + (1 - \gamma)\, t x_2.$$

According to the definition of Nash equilibrium, we have

$$c_B^* = c_C^*.$$

Hence, we have $\gamma = \frac{1}{4}$, $1 - \gamma = \frac{3}{4}$.

Last we can readily formulate the purchase cost of switchers from $x - x_1 - x_2$ between B and A targeted at the two firms,

$$c_A = p_A^1 + \omega\left(x - x_1 - x_2\right) t,$$
$$c_B = p_B^1 + (1 - \omega)\left(x - x_1 - x_2\right) t.$$

According to the definition of Nash equilibrium, we have

$$c_A^* = c_B^*.$$

Hence, we have $\omega = \frac{1}{4}$, $1 - \omega = \frac{3}{4}$.
We can solve for their profit function subsequently,

$$\begin{aligned}\pi_A^1 &= \left(p_A^1 - c\right)a + \left(p_A^1 - c\right)\frac{1}{4}x_1 + \left(p_A^1 - c\right)\frac{1}{4}(x - x_1 - x_2)\\ &= \left(p_A^1 - c\right)a + \left(p_A^1 - c\right)\frac{1}{4}(x - x_2),\end{aligned} \tag{9.6}$$

$$\begin{aligned}\pi_B^1 &= \left(p_B^1 - c\right)b + \left(p_B^1 - c\right)\frac{1}{4}x_2 + \left(p_B^1 - c\right)\frac{3}{4}(x - x_1 - x_2)\\ &= \left(p_B^1 - c\right)b + \left(p_B^1 - c\right)\left(\frac{3}{4}x - \frac{3}{4}x_1 - \frac{1}{2}x_2\right),\end{aligned} \tag{9.7}$$

$$\pi_C^1 = \left(p_C^1 - c\right)\frac{3}{4}(x_1 + x_2). \tag{9.8}$$

Through the comparison between these three profit functions and the profit functions of A, B in the first period in duopoly market, we can easily find that Firm C grabs $\frac{3}{4}x_1$ from Firm B and $\frac{3}{4}x_2$, respectively $\frac{1}{4}x_2$ from Firm A and $\frac{1}{2}x_2$ from Firm B. It is certain that Firm C rake in a part of market share of switchers in the first period. There is no doubt that Firm A and Firm B will lose a portion of their switchers, especially Firm B. See the Fig. 9.2.

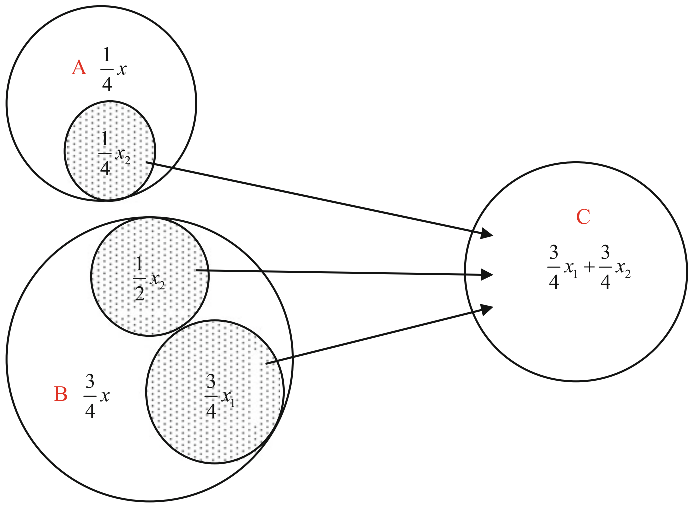


Fig. 9.2 Redistribution of the market share of switchers in the first period

9.2.2 Pricing Game of Three Firms in the Second Period

In order to rake in more consumers' surplus to pursue enormous profits, Firm A intends to strive for more switchers in the second period by charging this segment a lower price, while charging the loyal segment a constant price. However, Firm B can't stand by with nothing to do. Firm B will also fight for the switchers and consolidate the loyal segment through price discrimination. In the meantime, Firm C will also continue to cut price to deal with the pricing strategy of Firm A and Firm B. In a word, the two firms will try their best to reserve their own loyal segments which be charged at the same price as that in the first period and strive for more switchers which be charged at a lower price. The three firms will reach an equilibrium in the pricing game eventually.

Hence, define p_A^1 as Firm A's price charged for its loyal consumers in the second period, p_A^2 as Firm A's price charged for switchers in the second period. Similarly, define p_B^1 as Firm B's price charged for its loyal segment in the second period, p_B^2 as Firm B's price charged for switchers in the second period. Firm C won't implement price discrimination, so we only need to define p_C^2 as Firm C's price charged for switchers in the second period.

In order to reserve its own loyal consumers and then achieve customer recognition, Firm A must have

$$\begin{cases} p_A^1 < p_B^2 + t\left(x - x_1 - x_2\right), \\ p_A^1 < p_C^2 + t x_1. \end{cases} \tag{9.9}$$

Similarly, in order to reserve its own loyal consumers and then achieve customer recognition, Firm B must have

$$\begin{cases} p_B^1 < p_A^2 + t\left(x - x_1 - x_2\right), \\ p_B^1 < p_C^2 + t x_2. \end{cases} \tag{9.10}$$

In this period, according to the simple model above, it is easy to get

$$\begin{aligned} &\beta = \gamma = \omega = \frac{1}{2}, \\ &p_A^2 = p_B^2 = p_C^2 = c + t. \end{aligned} \tag{9.11}$$

Then, we can write down the three firms' profit functions,

$$\begin{aligned} \pi_A^2 &= \left(p_A^1 - c\right)a + \left(p_A^2 - c\right)\frac{1}{2}x_1 + \left(p_A^2 - c\right)\frac{1}{2}(x - x_1 - x_2) \\ &= \left(p_A^1 - c\right)a + \left(p_A^2 - c\right)\frac{1}{2}(x - x_2), \end{aligned} \tag{9.12}$$

$$\pi_B^2 = \left(p_B^1 - c\right) b + \left(p_B^2 - c\right) \frac{1}{2} x_2 + \left(p_B^2 - c\right) \frac{1}{2} (x - x_1 - x_2)$$
$$= \left(p_B^1 - c\right) b + \left(p_B^2 - c\right) \frac{1}{2} (x - x_1), \tag{9.13}$$
$$\pi_C^2 = \left(p_C^2 - c\right) \frac{1}{2} (x_1 + x_2). \tag{9.14}$$

Then, we need to confirm the value of p_A^1, p_B^1 and p_C^1 through the condition of reserving respective loyal segments of Firm A and Firm B in the second period.

Substitute p_A^1 from Eq. (9.2) and p_B^2 Eq. (9.11) into the first inequality in (9.9), we have

$$p_B^1 < c + t + \frac{1}{2} t (x_1 - x_2). \tag{9.15}$$

Substitute from Eqs. (9.2) and (9.11) into the second inequality in (9.9), we have

$$p_B^1 < c + t + \frac{1}{2} t (x_1 + x_2). \tag{9.16}$$

From the first inequality in (9.10), we have

$$p_B^1 < c + t + t (x_1 - x_2). \tag{9.17}$$

From the second inequality (9.10), we have

$$p_B^1 < c + t + t x_2. \tag{9.18}$$

According to Fixed Point Theorems, the equilibrium solution of p_B^1 reaches the sole critical value from the inequality (9.15) to (9.18). Hence, we have to gain the minimum of the right side of these inequalities.

Through comparison, there is no doubt that $c + t + \frac{1}{2} t (x_1 - x_2)$ is the minimum among $c + t + \frac{1}{2} t (x_1 - x_2)$, $c + t + t (x_1 - x_2)$ and $c + t + t (x_1 - x_2)$. Then, we need to focus on the comparison between $c + t + \frac{1}{2} t (x_1 - x_2)$ and $c + t + t x_2$.

If $c + t + \frac{1}{2} t (x_1 - x_2) < c + t + t x_2$, we have

$$x_1 < 3x_2.$$

Combining $x_2 < \frac{1}{4} x$, we can gain

$$x_1 < \frac{3}{4} x.$$

Obviously, it comes into existence all the time. That means we are bound to have

$$c + t + \frac{1}{2}t\left(x_1 - x_2\right) < c + t + tx_2.$$

Hence, $c + t + \frac{1}{2}t\left(x_1 - x_2\right)$ is the minimum of the right side of the inequalities from (9.15) to (9.18). In order to make these inequalities from (9.15) to (9.18) come into existence in the meantime,

$$p_B^1 = c + t + \frac{1}{2}t\left(x_1 - x_2\right). \tag{9.19}$$

Substitute from Eq. (9.19) into Eq. (9.2), we have

$$p_A^1 = c + t + t\left(x_1 - x_2\right). \tag{9.20}$$

Substitute p_B^1 from Eq. (9.19) into Eq. (9.3), we have

$$p_C^1 = c + t + \frac{1}{2}tx_1 - tx_2. \tag{9.21}$$

In order to testify the correctness of the value of p_A^1, p_B^1 and p_C^1, we can substitute from Eq. (9.21) into Eq. (9.1), we still have

$$p_A^1 = c + t + t\left(x_1 - x_2\right).$$

Hence, the value of p_A^1, p_B^1 and p_C^1 are all rational, we can continue our further analysis and comparison.

Under the prerequisite of reserving its loyal segment, first, let's compare π_A^1 from Eq. (9.6) and π_A^2 from Eq. (9.12) with p_A^1 and p_A^2.

Due to the same part of $\left(p_A^1 - c\right)a$ from π_A^1 and π_A^2, we only need to compare $\left(p_A^1 - c\right)\frac{1}{4}\left(x - x_2\right)$ and $\left(p_A^2 - c\right)\frac{1}{2}\left(x - x_2\right)$.

If $\pi_A^2 > \pi_A^1$, we have

$$\frac{1}{2}\left(p_A^2 - c\right)\left(x - x_2\right) > \frac{1}{4}\left(p_A^1 - c\right)\left(x - x_2\right). \tag{9.22}$$

Substitute p_A^2 solved from Eq. (9.11) and p_A^1 solved from Eq. (9.20) into the inequality (9.22), we have

$$x_1 - x_2 < 1.$$

That means it comes into existence all the time, namely, $\pi_A^2 > \pi_A^1$. Hence, Firm A will be better off through dynamic pricing based on price discrimination with customer recognition. In fact, the increased profit precisely comes from the expanding market share which wrests from Firm B and Firm C.

Then, under the prerequisite of reserving its loyal segment, let's compare π_B^1 from Eq. (9.7) and π_B^2 from Eq. (9.13) with p_B^1 and p_B^2 subsequently.

Due to the same part of $\left(p_B^1 - c\right) b$ from π_B^1 and π_B^2, we only need to compare $\left(p_B^1 - c\right) \frac{3}{4} (x - x_1 - x_2) + \left(p_B^1 - c\right) \frac{1}{4} x_2$ and $\left(p_B^2 - c\right) \frac{1}{2} (x - x_1 - x_2) + \left(p_B^2 - c\right) \frac{1}{2} x_2$.

We intend to compare respectively targeted at this situation where it is hard to recognize.

First, let's discuss $\left(p_B^1 - c\right) \frac{3}{4} (x - x_1 - x_2)$ and $\left(p_B^2 - c\right) \frac{1}{2} (x - x_1 - x_2)$. We can readily find that the former is greater than the latter.

Then, let's discuss the second part, $\left(p_B^1 - c\right) \frac{1}{4} x_2$ and $\left(p_B^2 - c\right) \frac{1}{2} x_2$.

If we have

$$\left(p_B^1 - c\right) \frac{1}{4} x_2 > \left(p_B^2 - c\right) \frac{1}{2} x_2. \tag{9.23}$$

Substitute p_B^1 solved from Eq. (9.19) and p_B^2 solved from Eq. (9.11) into the inequality (9.23), we have

$$\frac{1}{2} (x_1 - x_2) > 1.$$

Apparently, it is impossible because we acquiesce in the regularity condition which is $0 < x_2 < x_1 < x < 1$. That means what we have proposed that $\left(p_B^1 - c\right) \frac{1}{4} x_2 > \left(p_B^2 - c\right) \frac{1}{2} x_2$ is a wrong proposition. Hence, we have $\left(p_B^1 - c\right) \frac{1}{4} x_2 < \left(p_B^2 - c\right) \frac{1}{2} x_2$.

Then, we need to make a further comparison between the differences of the two parts above.

$$\begin{aligned} &\left(p_B^1 - c\right) \frac{3}{4} (x - x_1 - x_2) - \left(p_B^2 - c\right) \frac{1}{2} (x - x_1 - x_2) \\ &= t (x - x_1 - x_2) \left[\frac{1}{4} + \frac{3}{8} (x_1 - x_2)\right], \end{aligned} \tag{9.24}$$

$$\left(p_B^2 - c\right) \frac{1}{2} x_2 - \left(p_B^1 - c\right) \frac{1}{4} x_2 = t x_2 \left[\frac{1}{4} - \frac{1}{8} (x_1 - x_2)\right]. \tag{9.25}$$

Apparently, Eq. (9.24) is greater than Eq. (9.25) because $t (x - x_1 - x_2) > t x_2$ and $\frac{1}{4} + \frac{3}{8} (x_1 - x_2) > \frac{1}{4} - \frac{1}{8} (x_1 - x_2)$. Hence, we solve eventually

$$\pi_B^1 > \pi_B^2.$$

Firm B still can't benefit from the pricing game of three sides.

Last, it is obvious that $\pi_C^1 > \pi_C^2$. In fact, it is easily explained that Firm C can't make more profits in the second period because of charging a lower price for a smaller scale of consumers which contracts from three quarters to half. That means Firm C is also a loser in the pricing game. However, Firm C will pose a threat to Firm A and Firm B because of taking up a part of market share that originally belonged to them in duopoly market after all. With the development of Firm C, its strength keeping up with Firm B even Firm A, the new structure and distribution of market will come into being. The result of the pricing game will be another appearance.

9.3 Comparison

In fact, game theory is a very powerful way to model dynamic pricing. Even complex economic phenomena could sometimes be abstracted to two-player games for simplicity. But often, the interaction between several parties determines the real pricing success, which is more practical actually.

Then, we can make a complete comparison between the two analyses.

Firstly, from the perspective of academic development, although the research of a three-player game of dynamic pricing is gradually developing based on a two-player game of dynamic pricing, a pricing game of three sides which a new one joining in duopoly has been little discussed till now, while other respects surely discussed more, like a model concerning tripartite game among controlling shareholders, minority shareholders and managers involving agent problem and a model of dynamic games of three sides among the borrowing enterprises, guarantee enterprises and the banks for solving lending problems. Hence, what we discuss in this paper will enlighten the related research about dynamic pricing in the future; moreover, it is convenient to expand to a game of multiple sides.

Secondly, from the perspective of practice, the research of a pricing game of duopoly is certainly necessary, while a pricing game of three in this paper obviously processes more realistic meaning in our society. A complex market rather than a simple market existed in our daily life after all. Hence, the research a dynamic game of three sides seems to be representative. Duopoly or companies that want to join in the market where duopoly has existed will all be inspired.

Finally, through the comparison between the specific results of firms in these two situations, we conclude that firms which implement dynamic pricing based on price discrimination will be better off than those not. In addition, the firm which embraces a strong power of monopoly advantage and charges a higher price no matter in duopoly market or where added the third side is sure to make more profits through dynamic pricing based on price discrimination, while other participants are bound to be losers. In other words, the strong one in the market will take an absolute advantage of pricing over the poor one.

A pricing game of three is the easiest pricing game of multiple sides, we can continue to research dynamic pricing through a multiple-player game if necessary, which is more typical in the practice.

9.4 Conclusions

In a word, firms which implement dynamic pricing based on price discrimination will be better off than those not. Both of Firm A and Firm B in our case prove this point absolutely. In addition, we can reach a crucial conclusion that the firm which embraces a strong power of monopoly advantage and charges a higher price no matter in duopoly market or where added the third side is sure to make more profits through dynamic pricing based on price discrimination, while other firms will make less profit in the pricing game undoubtedly. Specifically speaking, the strong one will not only grab more market share of switchers but also ensure the profit of the loyal in the pricing game and get better off, while the poor one that charges a smaller scale of switchers a lower price in the second period though lock the profit of the loyal will be surely worse off. Hence, the strong one in the market will take an absolute advantage of pricing over the poor one. It seems that everything is more beneficial to the powerful in all fields, which may be the reason resulting in everybody being crazy to make themselves stronger and stronger.

We can discuss our research from two perspectives. Firstly, from a theoretical perspective, it is helpful for us to have an advanced comprehension of dynamic pricing practice and a pricing game of two or three. Secondly, from the perspective of practice, it identifies a rosy future for the strong one through dynamic pricing based on price discrimination.

In the future we can identify our advanced research by considering vertical product differentiation, inventory constraints, conversion cost. It is a good idea to research the real cases. And it will also be meaningful to analyze multi-period contracts of dynamic pricing. The third one in the market will obtain its loyal consumers in following periods after all. However, we can infer that the whole picture will have no change even though their respective profit functions will have change.

Acknowledgments Supported was provided by the National Natural Science Foundation of China (Grant No. 71401093) and the Fundamental Research Funds for the Central Universities (Grant No. 14SZYB08).

References

1. Anderson S (1987) Spatial competition and price leadership. Int J Ind Org 5(4):369–398
2. Balvers R, Szerb L (1996) Location in the hotelling duopoly model with demand uncertainty. Eur Econ Rev 40(7):1453–1461
3. Bass FM (1969) A new product growth for model consumer durables. Manag Sci 15:215–227
4. Bester H, Petrakis E (1995) Price competition and advertising in oligopoly. Eur Econ Rev 39(6):1075–1088
5. Chen Y, Zhang ZJ (2009) Dynamic targeted pricing with strategic consumers. Int J Ind Org 27(1):43–50
6. Clarke DG, Dolan RJ (1984) A simulation analysis of alternative pricing strategies for dynamic environments. J Bus S179–S200

7. Dang JF, Hong IH, Lin JM (2014) The cournot production game with multiple firms under an ambiguous decision environment. Inf Sci 266:186–198
8. Elsadany AEA (2014) A dynamic cournot duopoly model with different strategies. J Egypt Math Soc 35(1):116–130
9. Fleckinger P, Lafay T (2010) Product flexibility and price competition in hotelling's duopoly. Math Soc Sci 60(1):61–68
10. Gokhale CS, Traulsen A (2011) Strategy abundance in evolutionary many-player games with multiple strategies. J Theor Biol 283(1):180–191
11. Hotelling H (1929) Stability in competition. vol 39. Springer, Heidelberg
12. Kats A (1995) More on hotelling's stability in competition. Int J Ind Org 13(1):89–93
13. Levin Y, McGill J, Nediak M (2008) Risk in revenue management and dynamic pricing. Oper Res 56(2):326–343
14. Levin Y, McGill J, Nediak M (2009) Dynamic pricing in the presence of strategic consumers and oligopolistic competition. Manag Sci 55(1):32–46
15. Li H, Gan L, Zhou X (2014) Analysis of dynamic pricing based on price discrimination through two models. Int J Manag Sci Eng Manag 9(4):233–242
16. Liu Q, Zhang D (2013) Dynamic pricing competition with strategic customers under vertical product differentiation. Manag Sci 59(1):84–101
17. Narasimhan C (1988) Competitive promotional strategies. J Bus 427–449
18. Osborne MJ, Pitchik C (1987) Equilibrium in hotelling's model of spatial competition. Econ J Econ Soc 55:911–922
19. Raju JS, Srinivasan V, Lal R (1990) The effects of brand loyalty on competitive price promotional strategies. Manag Sci 36(3):276–304
20. Robinson B, Lakhani C (1975) Dynamic price models for new-product planning. Manag Sci 21(10):1113–1122
21. Sato K, Sawaki K (2013) A continuous-time dynamic pricing model knowing the competitor's pricing strategy. Eur J Oper Res 229(1):223–229
22. Şen A (2013) A comparison of fixed and dynamic pricing policies in revenue management. Omega 41(3):586–597
23. Van den Berg A, Bos I et al (2012) Dynamic cournot duopoly with intertemporal capacity constraints. Int J Ind Org 30(2):174–192
24. Von Neumann J, Morgenstern O (1944) Theory of games and economic behavior. Princeton University Press, Princeton
25. Wen Q, Fang H (2012) Analysis on the dynamic game model of smes group loans. Advan Appl Econ Financ 2(4):437–441
26. Xu H (2011) Study on investor protection under full circulation of stocks: analysis based on tripartite game among controlling shareholders, minority shareholders and managers. J Financ Econ 31:71–79
27. Xu A, Hu X, Gao S (2012) A three-player game analysis among governments, enterprises and consumers in the green supply chain of the home appliance industry. Sci Technol Manag Res 3:236–240
28. Yin S, Nishi T, Zhang G (2013) A game theoretic model to manufacturing planning with single manufacturer and multiple suppliers with asymmetric quality information. Procedia CIRP 7:115–120
29. Zhao J (1992) The hybrid solutions of an n-person game. Games Econ Behav 4(1):145–160

Chapter 10
Evaluating the Quality Performance of Reconstructive Community Public Health Service Based on Weighted TOPSIS Method

Siqi Jiang, Yang Li, Pengyan Jiang and Lu Gan

Abstract The evaluation of community public health services (CPHS) has received increasing attention in today's social environment. This study focuses on developing an evaluation model to test the quality of community public health service organizations, (CPHS) using a fuzzy Delphi method and weighted TOPSIS method. The main contributions of this paper are the evaluation system for reconstructive community public health service systems by using specific cases. Specifically, it can save resources in a reliable way by adopting a quantifiable evaluation index system, utilising software calculation methods, and combining the construction services. Moreover, the system can be easily used in CPHSO building after disasters.

Keywords CPHS · TOPSIS model · Disaster · Fuzzy method · Two stages to study

10.1 Introduction

In recent years, $\widetilde{CV}$ there has been a rebuilding of public health service systems in the disaster areas of China. To revitalize the provision of basic public health services, the Chinese central government launched the Health System Reform Plan in 2009. Key targets involve strengthening disease control and health promotion, as well as providing a package of basic public health services. This package includes; establishing health records for all citizens, managing chronic non-communicable diseases, increasing vaccine coverage for 15 vaccine-preventable diseases, implementing prevention and control programmes for major infectious diseases, and geochemical endemic diseases [5]. These all play an important role in community reconstruction. Also, evaluating scientifically and effectively on CPHS can lay a solid foundation for the construction of future CPHS.

S. Jiang · Y. Li · P. Jiang · L. Gan (✉)
School of Architecture and Urban and Rural Planning, Sichuan Agricultural University, Dujiangyan 611830, People's Republic of China
e-mail: ganlu_swe_1119@sina.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_10

Some scholars have put forward some research ideas. Ding [4] pointed out that we should consolidate the evaluation of organizations and set up a scientific system to evaluate, operate, and enhance the legal guarantees for quality evaluation. This resource experience is all from the quality research of Huaihsua city [4]. Hu [9] put forward a proposal to develop and evaluate an applicable model for CPHS in underdeveloped areas of China that ensures efficient, convenient and affordable primary health-care access for all residents [9]. Two previous studies have only focused on comprehensive performance evaluation, lacking the study of quality performance alone, have been short on reconstructed health service research, and weakened the quality evaluation of comprehensive performance assessments. The former ignored the fact that China is at an early stage of CPHS development and lacks quality performance evaluation systems with objective indicators. However, in this case, objective performance evaluation of CPHS systems is more scientific, more objective, and with steady applicability to primary stages. Therefore, this paper uses the weighted TOPSIS method to research the quality evaluation of reconstructive community public health service organizations, combined with specific cases. It analyzes service quality for the new reconstructed health institutions, and introduces improved schemes which have important practical significance.

Today, the development of China's health care system has lagged far behind its economic growth [11]. And objective quality evaluation is urgently needed to propel the development of CPHS system. Therefore, it is necessary to carry out quality performance evaluations and establish an evaluation model while China is at the developmental stage. Thus, this paper applies two stages to study including model establishment and case analysis that has simple, clear, and easy to understand examples. This paper mainly uses the research methods of the fuzzy analytic hierarchy process (AHP), the literature methodology, and weighted TOPSIS method as well as case analysis. Main content includes: first, to establish the evaluation index system and determine the weight. Second, to establish the CPHS quality evaluation model basing on the weighted TOPSIS method, and next to take Dujiangyan city as an example for the model. Finally, to analyze and summarize the strengths and weaknesses of CPHS institutions quality.

The method adopted in the established model can be extended easily. For example, it also can deal with other management decision-making problems no matter whether the data are quantitative or qualitative. Furthermore, TOPSIS uses Euclidean distance theory in fuzzy data analysis and ranks research objects, so it is quite objective [12, 15]. Through the literature research on CPHS quality, which makes the evaluation index more scientific. In addition, the evaluation angle selected in this paper can fill the gap that study on the reconstructive health service organization and performance evaluation for health service using objective indexes in China. In the meantime, using Matlab to model can directly and quantitatively describe the current situation of CPHS organizations built after a disaster. Moreover, the evaluation conclusion not only provides some basis to promote existing health institutions, but also be used as guiding ideology for planning or establishing health service institutions in the future. The remainder of this article is as follows: Sect. 10.2 focuses on the problem statement and the research train of thought. Section 10.3 describes the method of TOPSIS modeling including literature research, the tendency of normalization and ideal solution, and the index sorting. Section 10.4 presents the actual case calculations, and the results and analysis of the improvement plan. Research limitations, further research methods and suggestions are discussed in Sect. 10.5.

10.2 Problem Statement

The problem in this paper focuses on how to establish an evaluation index, ways to improve evaluation models in order to make them accurate more, and analyzes the evaluation results, and gives a scientific and reasonable solution.

Weighted TOPSIS method is used to evaluate the CPHS quality. This way is better than the RSR method and principal component analysis (PCA), which will help improve the community health service quality levels overall. RSR can only reflect the difference on comprehensive rank, and does not reflect the degree of overall size difference. The rank's conversion about original indicators will lose part of the original data, and reduce then reduce the efficiency of evaluation. Principal component analysis has ambiguity. This means it is unlike the original variables, which are clear and precise [1, 7]. But the weighted TOPSIS method can overcome these shortcomings. TOPSIS is the pretested method because it compares each alternative directly depending on the data in the evaluation matrices and weights.

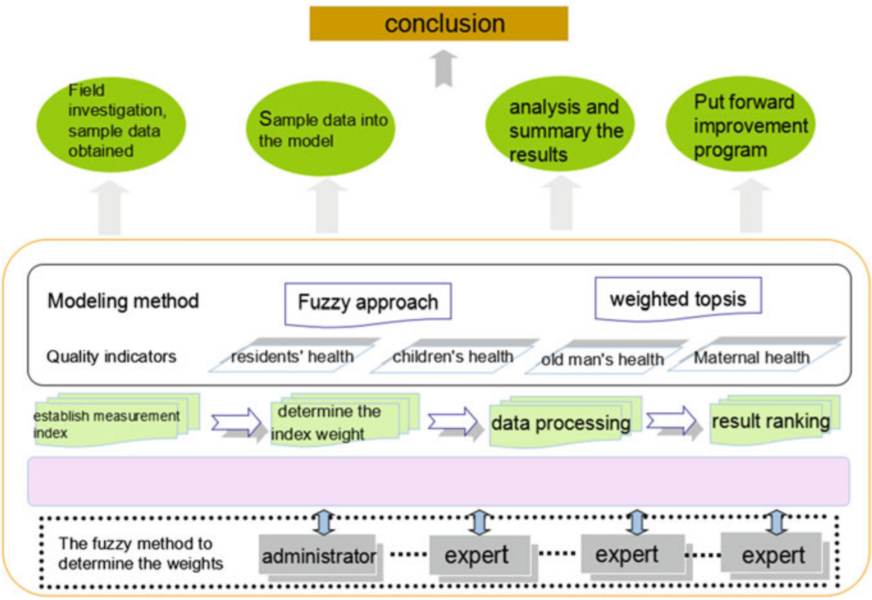


Fig. 10.1 Flow chat for research process

Due to its logical reasoning, the method has solved many real-world problems. Especially in recent years in the Asian Pacific region [13]. The research train of thought is shown as the Fig. 10.1.

10.3 Modelling

10.3.1 Screening Evaluation Indexes and Weights

Indexes are screened according to the standards The 2011 National Basic Public Health Services Project Specification, and The 2012 Standards of Basic Public Health Service Performance Evaluation in Sichuan Province [8, 14]. Then, the important weights for various indexes have been given in Table 10.1.

Then, the weights are determined though expert estimation method. Suppose factor set $U = \{u_1, u_2, \ldots, u_n\}$, and 4 experts gave the weight of all factors $\{u_i\}(i = 1, 2, \ldots, n)$ independently, as Table 10.2:

Table 10.1 The service quality evaluation indexes and weights

Secondary indicators	Level 3 indicators	Code name	The weight
Residents' health records management	Residents' health records standardized by inputting rate	X_1	0.372
Health education	Public health education and consultation times a year	X_2	0.149
Vaccination	The immune planning vaccination rate	X_3	0.083
	0–6 years old child vaccination certificate rate is established	X_4	0.041
The prevention and treatment of infecting us diseases	Tuberculosis (TB) by inputting rate	X_5	0.041
Kids' health management	The rate of Children system management	X_6	0.083
Maternal health management	The rate of prenatal health	X_7	0.033
	The rate of high risk	X_8	0.033
Seniors health management	The rate of elderly residents health	X_9	0.083
Health management for patients with chronic diseases	The rate of high blood pressure patients health	X_{10}	0.041
	The rate of patients with type 2 diabetes health	X_{11}	0.041

Table 10.2 The weight of each factor

Expert	Factor											$\sum$
	u_1	u_2	u_3	u_4	u_5	u_6	u_7	u_8	u_9	u_{10}	u_{11}	
Expert 1	0.367	0.151	0.085	0.046	0.04	0.085	0.032	0.028	0.081	0.039	0.046	1
Expert 2	0.375	0.143	0.084	0.039	0.044	0.078	0.035	0.035	0.082	0.047	0.038	1
Expert 3	0.374	0.153	0.08	0.038	0.039	0.086	0.032	0.036	0.086	0.037	0.039	1
Weight a_i	$\frac{1}{k}\sum_{j=1}^{k} a_{1j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{2j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{3j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{4j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{5j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{6j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{7j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{8j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{9j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{10j}$	$\frac{1}{k}\sum_{j=1}^{k} a_{11j}$	1
$i = 1, \ldots, n$ Weight	0.372	0.149	0.083	0.041	0.041	0.083	0.033	0.033	0.083	0.041	0.041	1

10.3.2 Data Processing

(1) Establish the Original/Decision Data Matrix

TOPSIS method begins with a decision matrix with raw data having 'n' criteria/attributes and 'm' alternatives and the decision matrix can be represented as:

$$D = \begin{pmatrix} X_{11} & X_{12} & X_{13} & \cdots & X_{1n} \\ X_{21} & X_{22} & X_{23} & \cdots & X_{2n} \\ X_{31} & X_{32} & X_{33} & \cdots & X_{3n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{m1} & X_{m2} & X_{m3} & \cdots & X_{mn} \end{pmatrix},$$

where, X_{ij} is the performance of the ith alternative with respect to jth attribute [10] (Table 10.3).

The following is caption with data:

Decision matrix D:

$$\begin{pmatrix} 45\,\% & 6 & 90\,\% & 100\,\% & 100\,\% & 74\,\% & 78\,\% & 100\,\% & 60\,\% & 32\,\% & 33\,\% \\ 40\,\% & 4 & 90\,\% & 100\,\% & 100\,\% & 70\,\% & 75.6\,\% & 100\,\% & 54\,\% & 30\,\% & 30\,\% \end{pmatrix}.$$

(2) Standardizing The Indicators

Standardize each indicators into become of the same direction [2].

For positive indicators (X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}) in this case study): $X_{ij} = x_{ij}; i = 1, 2, \ldots, m; j = 1, 2, \ldots, n$

For negative indicators:

(a) If the value is a relative number, use the difference method.

$$X_{ij} = 1 - x_{ij}; \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n$$

(b) If the value is an absolute number, it will be transformed to its reciprocal number.

$$X_{ij} = 1/x_{ij}; \quad i = 1, 2, \ldots, m; \quad j = 1, 2, \ldots, n$$

There is no negative indicator in the evaluation index, so no need to transform.

(3) Normalize the Decision Matrix

Table 10.3 Optimal solution for the case study

	X_1 (%)	X_2	X_3 (%)	X_4 (%)	X_5 (%)	X_6 (%)	X_7 (%)	X_8 (%)	X_9 (%)	X_{10} (%)	X_{11} (%)
Ping Yi	45	6	90	100	100	74	78	100	60	32	33
Shang You	40	4	90	100	100	70	75.60	100	54	30	30

For the influence of different index dimensions, we normalized the measured value of the index. Normalized decision matrix is calculated by making use of elements of matrix D and using the following formula: $a_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{m} X_{ij}^2}}$ and establish the normalized matrix as $A = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{pmatrix}$.

(4) To Determine the Ideal Solution and the Negative Ideal Solution:

Ideal Solution:

$$A^{+} = (\max_{i} a_{ij} \mid j \in J_1), (\min_{i} a_{ij} \mid j \in J_2) i = 1, 2, \ldots, m \quad j = 1, 2, \ldots, n.$$

Negative idea solution:

$$A^{-} = \left(\min_i a_{ij} \mid j \in J_1\right), \left(\max_i a_{ij} \mid j \in J_2\right), i = 1, 2, \ldots, m \quad j = 1, 2, \ldots, n.$$

(5) Calculating Distance Scale

Namely, the distance between the ideal solution and the negative ideal solution, the distance can be calculated by n-dimensional Euclidean distance. Di^{+} is the distance from index to idea solution A^{+}, to anti ideal solution A^{-} is D^{i-}.

$$D_i^{+} = \sqrt{\sum_{j=1}^{m} \omega_j \left(a_{ij}^{+} - a_{ij}\right)^2} \quad D_i^{-} = \sqrt{\sum_{j=1}^{m} \omega_j \left(a_{ij}^{-} - a_{ij}\right)^2}, \quad i = 1, 2, \ldots, m.$$

(6) Calculate the Closeness of Each Index and Optimal Solution

The relative closeness of a product, (or alternative) X_i with reference to positive ideal solution A^{+} is calculated as follows [3]:

$$C_i = \frac{D_i^{-}}{D_i^{+} + D_i^{-}} \quad i = 1, 2, \ldots, m \quad 0 \leq C_i \leq 1.$$

When $C_i = 0$, $A_i = A^{-}$, indicates that the object is the worst one when $C_i = 1$, $A_i = A^{+}$, indicates that the object is the optimal one. But in actual multi-objective decision making, the possibility of the optimal target and the worst target is very small.

(7) The Result

Sort the objects according to the value size for C_i, the bigger the value is better. The highest value is for the best bid evaluation target.

10.4 Case Analysis

10.4.1 Source

Data used in this study is from Shang You Community Health Station, Shang Yang Community Health Station and Yi Jie Community Health Station of Dujiangyan city, China. The data is in Table 10.4.

Then we established the original data matrix as follows:

$$\begin{pmatrix} 100\,\% & 12 & 97.6\,\% & 100\,\% & 98\,\% & 95\,\% & 93\,\% & 100\,\% & 10.9\,\% & 50\,\% & 40\,\% \\ 100\,\% & 12 & 95.1\,\% & 100\,\% & 98\,\% & 94\,\% & 93\,\% & 100\,\% & 10\,\% & 50\,\% & 40\,\% \\ 100\,\% & 12 & 95.7\,\% & 100\,\% & 97\,\% & 94\,\% & 92\,\% & 100\,\% & 12\,\% & 49\,\% & 40\,\% \\ 100\,\% & 12 & 96.3\,\% & 100\,\% & 95\,\% & 90\,\% & 85\,\% & 100\,\% & 10\,\% & 47\,\% & 38\,\% \end{pmatrix}$$

10.4.2 Data Processing and Result

(1) All the data was entered into the computer, and Matlab programming steps are as follows:

Step 1. $A = \text{Formulation}(A)$
Step 2. $A = \text{Weighting}(A)$
Step 3. $(X^{+}, X^{-}) = \text{Find Ideal Points}$
Step 4. $D = \text{Computing Distance}(A, X^{+}, X^{-})$
Step 5. $C = \text{Computing Degree}(D)$
Step 6. $R = \text{Sorting}(C)$

(2) Consequence

The normalized matrix:

$$A = \begin{pmatrix} 0.5000 & 0.5000 & 0.5074 & 0.5000 & 0.5051 & 0.5093 & 0.0101 & 0.5000 & 0.5067 & 0.5100 & 0.5062 \\ 0.5000 & 0.5000 & 0.4944 & 0.5000 & 0.5051 & 0.5039 & 0.0101 & 0.5000 & 0.4648 & 0.5100 & 0.5062 \\ 0.5000 & 0.5000 & 0.4975 & 0.5000 & 0.5000 & 0.5039 & 0.9999 & 0.5000 & 0.5578 & 0.4998 & 0.5062 \\ 0.5000 & 0.5000 & 0.5006 & 0.5000 & 0.4897 & 0.4825 & 0.0092 & 0.5000 & 0.4648 & 0.4794 & 0.4809 \end{pmatrix}.$$

Table 10.4 Optimal solution for the case study

	X_1 (%)	X_2	X_3 (%)	X_4 (%)	X_5 (%)	X_6 (%)	X_7 (%)	X_8 (%)	X_9 (%)	X_{10} (%)	X_{11} (%)
Ping Yi	100	12	97.6	100	98	95	93	100	10.9	50	40
Shang You	100	12	95.1	100	98	94	93	100	10	50	40
Yi Jie	100	12	95.7	100	97	94	92	100	12	49	40
Shang Yang	100	12	96.3	100	95	90	85	100	10	47	38

The ideal solution:

$$A^{+} = \left(0.5000\ 0.5000\ 0.5074\ 0.5000\ 0.5051\ 0.5093\ 0.9999\ 0.5000\ 0.5578\ 0.5100\ 0.5062\right).$$

The negative ideal solution:

$$A^{-} = \left(0.5000\ 0.5000\ 0.4944\ 0.5000\ 0.4897\ 0.4825\ 0.0092\ 0.5000\ 0.4648\ 0.4794\ 0.4809\right).$$

10.4.3 The Meanings of Results and Analysis Processing

Health service quality in Pingyi is now optimal, followed by Shangyou, and Shangyang is the least optimal. After the earthquake happened in 2008, Pingyi health service center was completed rebuilt. Now all evaluation indexes are excellent and conform to the highest standards situation after 2012. Under Pingyi, Shangyou and Yijie health stations started to establish new CPHS systems. These disease prevention and health care, general medical, maternal and child health care, rehabilitation treatment, health education, planned immunization, and guidance of family planning. Due to limitations of space and resources, the service quality in Shangyang and Yijie is lower than that of Pingyi. The operating space available is just one or two small storefronts, medical staff of 2–3, and insufficient medical apparatus and instruments (Table 10.5).

Shangyang community is an new residential area replacing Qingcheng mountain community after the earthquake. The permanent population is 1283, more than 70 % are elderly, as a result, the physician index X_9 is higher than other three communities. The station serves residents with a small shop facade and all indexes are low, especially index X_6 and X_7 which are far below Pingyi, Shangyou and Yijie. The solution Shangyang community health service station is the smallest and it can be a merger with Yijie community to increase the size of the two CHPS posts. In this way, the business scale of two can be expanded to share resources and reduce resource waste. Also, it allows residents to see a doctor more conveniently because Yijie community is next to Shangyang. For Pingyi health service center, it should improve the quality of medical equipment, and promote more public health knowledge in order to

Table 10.5 The sorting result of all CPHS organizations

Name of institution	C_i	Ranking
Shang Yang community health service stations	0.86	2
Yi Jie community health service stations	0.81	3
Shang Yang community health service stations	0.08	4
Ping Yi community health service center	0.92	1

C_i: the proximity between health service quality and the optimal value improve residents' health consciousness so as to improve the indicators X_9, X_{10} and X_{11}. Furthermore, it should continue play a leading role to promote the development of Shangyou and Yijie health posts.

10.5 Conclusion

This paper eliminates the index dimensional effect, makes full use of original data on sorting results, reflects the degree of different evaluation units quantitatively [6], and operates easily by using the weighted TOPSIS method. It is reliable to reflect the new public health service situation of YiJie community, Dujiangyan city. The result of the research provides scientific basis for community health service quality management, improving China's health system. Considering time, effort and funding constraints, we just investigated three health stations and one health center, so sample size is a little low and representativeness of the study result may be insufficient.

There are three areas suggested for future research. First, more health stations need to be investigated to ensure the credibility of the study result. Secondly, make the index connotation definition more scientific. Finally, explore the method of quality evaluation and testing further. Each of these areas is very important and equally worthy of our concern.

Acknowledgments This research was supported by the Youth Funds of Sichuan Provincial Education Department (Grant NO.14ZB0014), the Key Funds of Sichuan Social Science Research Institute "System Science and Enterprise Development Research" (Grant NO. Xq15B09), and the Humanities Social and Sciences Research Funds of Education Ministry (Grant no.15XJC630001).

References

1. Baykasoğlu A, Gölcük I (2015) Development of a novel multiple-attribute decision making model via fuzzy cognitive maps and hierarchical fuzzy topsis. Inf Sci 301:75–98
2. Chen F, Wang J, Deng Y (2015a) Road safety risk evaluation by means of improved entropy topsis-RSR. Saf Sci 79:39–54
3. Chen K, Kou G et al (2015b) Visualizing market structure through online product reviews: Integrate topic modeling, topsis, and multi-dimensional scaling approaches
4. Ding J (2012) The current situation of community health service quality evaluation and countermeasures research. PhD thesis, Xiangtan University, (in Chinese)
5. Ding Y, Smith HJ et al (2013) Factors influencing the provision of public health services by village doctors in Hubei and Jiangxi provinces, China. Bull World Health Org 91(1):64–69
6. Gao C, Wei D et al (2013) A modified evidential methodology of identifying influential nodes in weighted networks. Physica A Stat Mech Appl 392(21):5490–5500
7. Han D (2012) Evaluation of the quality of hospital medical comprehensive evaluation method research, pp 15–21, (in Chinese)
8. General Office of the Ministry of Health (2013) Sichuan province demonstration in 2012 community health service center of evaluation index system, pp 1–6, (in Chinese)
9. Hu H, Liang W et al (2010) Establishment and evaluation of a model of a community health service in an underdeveloped area of China. Public Health 124(4):206–217

10. Jayant A, Gupta P et al (2014) Topsis-ahp based approach for selection of reverse logistics service provider: a case study of mobile phone industry. Procedia Eng 97:2147–2156
11. Liu H, Gao S, Rizzo JA (2011) The expansion of public health insurance and the demand for private health insurance in rural china. China Econ Rev 22(1):28–41
12. Saremi M, Mousavi SF, Sanayei A (2009) TQM consultant selection in smes with topsis under fuzzy environment. Expert Syst Appl 36(2):2742–2749
13. Sekhar C, Patwardhan M, Vyas V (2015) A Delphi-ahp-topsis based framework for the prioritization of intellectual capital indicators: a SMEs perspective. Procedia Soc Behav Sci 189:275–284
14. Sichuan Province Health Department of Sichuan Province (2010) Community basic public health service project performance evaluation method, pp 13–16, (in Chinese)
15. Xu S, Zhang C, Yang J (2013) The topsis evaluation on carbon emission economic efficiency. Asian Agric Res 5(6):1

Chapter 11
Artificial Intelligence for Concentrated Solar Plant Maintenance Management

Alfredo Arcos Jiménez, Carlos Quiterio Gómez Muñoz, Fausto Pedro García Marquez and Long Zhang

Abstract Concentrated Solar Power (CSP) is an alternative to the conventional energy sources which has had significant advances nowadays. A proper predictive maintenance program for the absorber pipes is required to detect defects in the tubes at an early stage, in order to reduce corrective maintenance costs and increase the reliability, availability, and safety of the concentrator solar plant. This paper presents a novel approach based on signal processing employing neuronal network to determine effectively the temperature of pipe, using only ultrasonic transducers. The main novelty presented in this paper is to determine the temperature of CSP without requiring additional sensors. This is achieved by using existing ultrasonic transducers which is mainly designed for inspection of the absorber tubes. It can also identify suddenly changes in the temperature of the CSP, e.g. due to faults such as corrosion, which generate hot spots close to welds.

Keywords Fault detection and diagnosis · Electromagnetic sensors · Macro fiber composite · Wavelet transforms · Non destructive tests · Neuronal network

11.1 Introduction

Due to the continuous growth in electricity needs in the world, power production from renewable energy sources has been primarily used up to cover the energy demand. This need has caused significant growth and development of new Concentrated Solar Power. Figure 11.1 shows the growth of solar thermal power generation in Spain between 2007 and 2011.

A.A. Jiménez · C.Q.G. Muñoz · F.P.G. Marquez (✉)
Ingenium Research Group, Castilla-La Mancha University, Ciudad Real, Spain
e-mail: FaustoPedro.Garcia@uclm.es

L. Zhang
School of Electrical and Electronic Engineering, Faculty of Engineering and Physical Sciences, University of Manchester, Manchester, UK

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_11

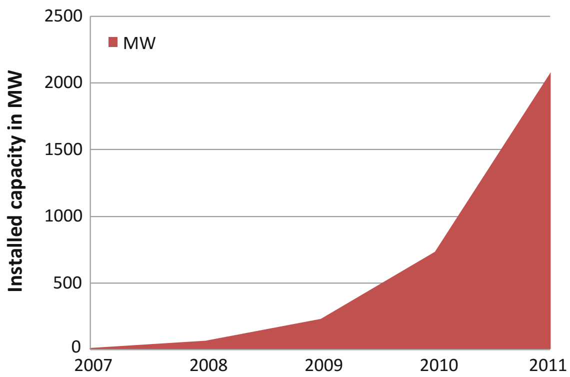


Fig. 11.1 Growth in installed solar thermal power generation capacity of Spain (projects in operation). An astounding total of 14,231 MW in potential solar thermal projects is currently under consideration in Spain [13]

CSP requires to improve the operational and maintainability of this plants because a failure can halt production of an entire power plant [5, 6, 21]. A proper condition monitoring system [17] is necessary to analyze those critical elements of the plant, such as the absorber tubes and welds [4, 11, 14, 18].

Non-destructive testing (NDT) for fault detection in structures such as pipes has gained significant attention in recent years due to noteworthy advances in instrumentation technology and digital signal processing. The capability of NDT to prevent the evolution of faults to catastrophic failures is one of its main advantages, increasing the reliability, availability and maintainability of the system.

Within the NDT field, guided waves are a technique widely employed for structural health monitoring. This technology is based on the excitation of ultrasonic waves that propagate through the pipe over long distances. It allows inspection of larges distances without relocation of the transducers [20].

Most of the absorber pipes are made of austenitic stainless steel, whose properties can be exposed to large temperature ranges. The ultrasonic waves are sensitive to the temperature changes because it modify properties of the steel like: density, Youngs modulus and Poisson ratio. Temperature changes directly affect to the propagation velocity and attenuation modifying the waveform the ultrasonic pulses. These changes are difficult to detect with traditional methods of signal processing, so it has become necessary to seek for new techniques to find patterns within the signal at a certain temperature.

Neuronal networks have shown to be a very useful tool for pattern recognition within signals [15]. In this work, a type of neuronal network has been used to train and recognize temperatures ranges in a test rig that simulate the working conditions of a CSP.

11.2 Methodology

The aim of this work is to determine the temperature of the tubes only by using piezoelectric sensors. It can lead to cost savings and to optimize the number of structural health monitoring sensors of a CSP [14, 16]. It was carried out emissions of ultrasonic short pulses at different temperatures, and the signals were processed to train a neuronal network. The output of the neuronal network allows knowing the temperature of the pipe (Fig. 11.2).

11.2.1 Data Collection

The experiment was carried out in a test rig (Fig. 11.3) consisting in 316 L austenitic stainless steel tubes, four meters long, similar to those used in CSP, whereby oil is circulated at high temperature. Two Macro Fiber Composite (MFC) transducers were placed in the test rig, where one acts as a transmitter and the other as receiver (pitch and catch). The transmitter transducer generates short pulses (6 cycles) of 250 kHz. The receiver transducer collects the ultrasonic wave, by converting the mechanical

Fig. 11.2 Process flow

Fig. 11.3 Test rig: austenitic stainless steel pipes

movement of the wave into electrical signal [7]. Also the temperature is collected by using a thermocouple on the pipe, in order to train the neuronal network.

The oil that circulates inside the pipes was heated from 25 to 75 °C and the external surface of the pipereached 55 °C. During the heating of the experimental platform were collected 1100 ultrasonic signals with their respective temperatures.

11.2.2 Signal Pre-processing

The signal obtained must be conditioned in order to properly train the neuronal network. For this purpose has been used wavelet transform to perform a signal denoising.Wavelet transform has been shown to be a powerful tool to remove noise and to extract the relevant information within the signal [3, 9, 10]. The Daubechies family of Wavelets was chosen to perform the signal denoising.

11.2.3 Feature Extraction from Ultrasonic Signal

110 signals are obtained for each temperature measurement and each signal contains 2000 samples. If each sample is considered an input of the neuronal network, in this case, to have a large number of inputs, would generate a high number of learning patterns and therefore, the error would be significant. Otherwise, it would be producing an over learning network, which degrades the generalization ability of the neuronal network. This is called the curse of dimensionality [1, 2, 8].

It is necessary to use a technique that allows reducing the number of inputs while maintaining the characteristic signal information. The characteristic coefficients of each ultrasonic signal were extracted by using the autoregressive model AR, by employing the Yule–Walker equations [12].

The ultrasonic signals provide different parameters, such as waveform, peaks, energy, amplitude, etc., that are used for pattern recognition. The knowledge in this field aids to select such parameters. The results obtained have been verified with trial and error.

Different classical approaches have been employed in order to achieve adequate results for neural networks, e.g. time domain (time of flight of the ultrasonic echoes of the signal, maximum amplitude, peak position, rise time and descent time, energy, etc.) or frequency domain (arithmetic mean, mode, standard deviation or variance). However, the outcomes of these methods are not accurate enough.

The method autoregressive (AR) of Yule–Walker are an example of parametric approaches. They calculate the power spectral density estimating the linear coefficients of a hypothetical system that generates the first signal. These methods tend to produce better results than conventional techniques, when the length of the available signal is relatively short.

In the spectral analysis used in this document a parametric estimator based on the model used Yule–Walker.

11.2.4 Pattern Recognition by Neuronal Network (Multilayer Perceptron)

For pattern recognition has been used a Neural Network Unidirectional supervised through a Multilayer Perceptron (MLP) with training by back propagation algorithm [25]. The inputs of the NN are the AR coefficients of the ultrasonic signal and the outputs are the temperature rages of the experiments. It has been stablished 11 ranges between 25 and 55 °C, whereby each range comprises 2.7 °C.

The structure is three layers of processing units as you can see (Fig. 11.4) and mathematically expressed by:

The Eq. (11.1) is the general equation of the neuronal network,

$$z_k = \sum_j w'_{kj} y_j - \theta'_i = \sum_j w'_{kj} f\left(\sum_i w_{ji} x_i - \theta_j\right) - \theta'_j, \tag{11.1}$$

where: x_i is input neural network; x_i is output of the hidden layer; z_i is output final layer; t_k is output targets; $w_j i$ is weight hidden layer; w'_{kj} is weight final layer; θ_j is bias hidden layer; θ'_k is Bias final layer.

And the chosen activation function of the neuronal network is the sigmoid function. The sigmoid function is shown in Eq. (11.2), and plotted in Fig. 11.5.

$$f(x) = \frac{1}{1 + e^{-x}}. \tag{11.2}$$

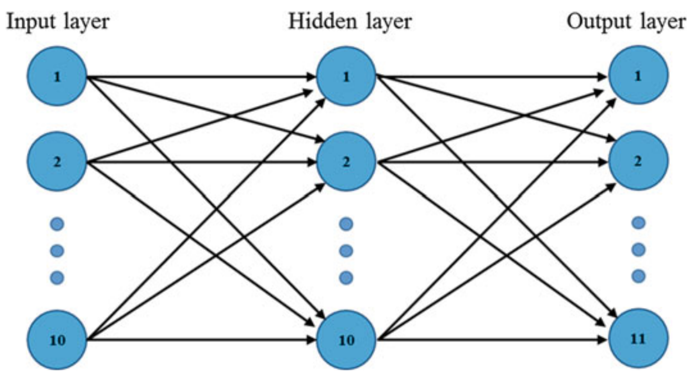


Fig. 11.4 Multilayer perceptron scheme, where the inputs are the AR parameters, and the outputs are the temperature

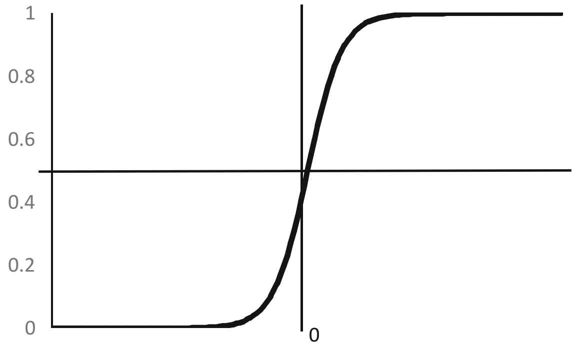


Fig. 11.5 Sigmoid activation function

The steps used to achieve the results with the neuronal network are described.

(1) Set of samples

As mentioned in the previous section, the input of the neuronal network is introduced the extracted characteristics of the signal. The architecture of the neuronal network, and the configuration of the hidden layer, depending on the structure of the input data. In this work it has been tested the following input parameter of the signal: AR (2), AR (5), AR (10), AR (15) and AR (20).

(2) Extraction of the training set, test and validation

Samples the set of signals we performed in order to generalize the network (cross validation) apart in sets:

Training: 70 %; Validation: 15 %; Test: 15 %

On the other hand we have selected another set of signals (15 %) to perform a check on the external network to test modes.

(3) Architecture design of multilayer Perceptron

It has been designed a neural network with one hidden layer because it has been found empirically that networks with multiple hidden layers are more prone to getting caught in undesirable local minima. Therefore we have proceeded to use with a single hidden layer.

It has tested different neural network architectures based on patterns obtained in the experimental phase. First it was tested with a Multilayer Perceptron 05/02/11 (first layer with two input neurons, hidden layer with five neurons and output layer of 11 neurons). Later we were increasing the number of inputs, the number of hidden neurons, to achieve the desired objectives.

(4) Learning process

Back propagation is one of the simplest and most general methods for supervised training of multilayer neural networks. Other methods maybe faster or have other desirable properties, but few are more instructive.

We have used two training modes back propagation algorithm:

- Gradient descent with momentum and adaptive learning rate back propagation and performance mean square error (MSE) [24, 26].
- Scaled conjugate gradient and performance Cross Entropy [19, 23].

In the second case we obtained best results with higher performance.

We have used a second-order analysis of the error in order to determine the optimal rate of learning through algorithm conjugate gradient based on performing gradient descent using also information provided by the rate of change of slope. It is the second derivative of the error:

$$H = \frac{\partial^2 E(W)}{\partial w_{ij} \partial w_{kl}} \text{(Hessian matrix)}. \tag{11.3}$$

This algorithm uses different approaches that avoid the hard work that represents the direct calculation.

During the learning process, the MLP goes through stages in which the reduction of the error can be extremely slow. These periods of stagnation can influence learning times. In order to resolve this problem we propose to replace the mean square error (MSE) by cross entropy error function. Simulation results using this error function show a better network performance with a shorter stagnation period.

(5) Early stopping

One way to dealing with the overfitting problem is to extract a subset of samples of the training set (note that the whole test previously extracted) and use of auxiliary way during training [22].

This subset is called validation set. The role of the validation set is to evaluate the network error after each epoch (or after every few epochs) and determine when this starts to increase. Since the validation set is left outside during training, the error about is a good indication that the network error will commit on the test set. Consequently, the procedure to stop the workout at the time the validation error and increase the values of the weights of the previous epoch are preserved.

11.3 Results

During the design of the architecture of neural network, it has been determined the following parameters:

(1) Number of inputs to define the neural input layer: The original signals with the relevant information of the received ultrasonic pulses is composed by 2000 samples: The number of inputs is significantly reduced after extracting the characteristics of the signal through the method of autoregression (AR). Network has been tested with different inputs as can be seen in Fig. 11.6, and the AR-10 method provides better results.
(2) Numbers of outputs. A neuronal network with fewer outputs have better results that with more outputs. It was decided to have more outputs for the range of temperature range were lower. Thus, each range has a range of 2.7 °C, corresponding to eleven outputs elected.

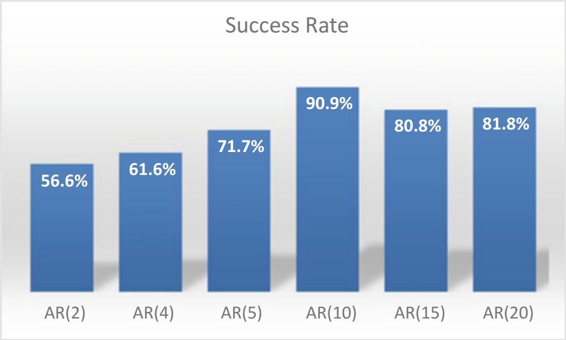


Fig. 11.6 Success rate of the AR employed

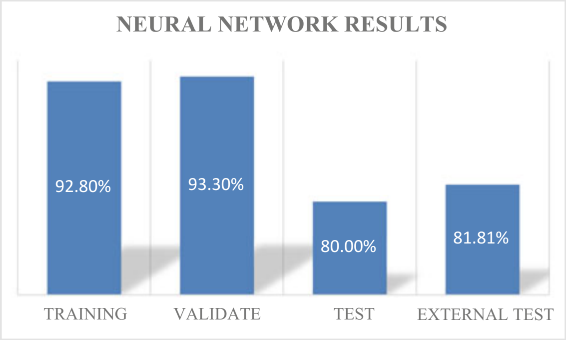


Fig. 11.7 Success rate of the neural network to determine the temperature range

(3) The numbers of neurons in the hidden layer is treated by many authors problem. There is criteria based on the number of inputs and training patterns. This is one of the main problems of MLP. For the calculation of the hidden neurons we've had on one hand the network performance through the mean square error and on the other the number of patterns to train.In this study we have trained, validated and tested with ultrasonic 990 signals, leaving 110 signals for further test in order to generalize the neural network.

(4) Scaled conjugate gradient and performance Cross Entropy has been training mode chosen as the best performance.

The established neural network architecture has been trained with the following results (Fig. 11.7):

11.4 Conclusion

The paper presents a novel methodology that allows increasing the reliability of a condition monitoring system analysing the temperature of the absorber tubes employing ultrasonic waves in a Concentrate Solar Plant (CSP). The approach can detect a temperature due to a potential failures, such as hot spots in defects in welds. This technique allows avoiding redundancy of sensors, since a specific number of ultrasonic transducers can determine the structural condition of the tube and its temperature, using guided waves. A test rig, that simulates the working conditions of the absorber pipes of a CSP, was built to carry out the experiments. The oil inside the pipes was heated and circulated in the installation, while the pitch and catch of ultrasonic pulses were carried out. A neuronal network has been designed for signal processing and pattern recognition in order to identify the conditions. In order to reduce the inputs of the neuronal network, the ultrasonic signals have been pre-processed and their characteristic parameters have been extracted employing autoregressive methods. The trained neuronal network can determine the temperature of the test rig with an accuracy of 2.7 °C.

Acknowledgments The work reported herewith has been financially supported by the Spanish Ministerio de Economía y Competitividad, under Research Grant DPI2015-67264.

References

1. Bishop CM (1994) Neural networks and their applications. Rev Sci Instrum 65(6):1803–1832
2. Del Brio BM, Molina AS (2001) Redes neuronales y sistemas borrosos: introducción, teoría y práctica/Bonifacio Martín del Brio, Alfredo Sanz Molina
3. García Márquez FP, García-Pardo IP (2010) Principal component analysis applied to filtered signals for maintenance management. Qual Reliab Eng Int 26(6):523–527
4. García Márquez FP, Muñoz G et al (2014) Structural health monitoring for concentrated solar plants
5. Gómez CQ, Villegas MA et al (2015) Big data and web intelligence for condition monitoring: a case study on wind turbines. Handbook of research on trends and future directions in big data and web intelligence; Information Science Reference, IGI Global: Hershey, PA, USA
6. Gomez Munoz C, Gonzalez-Carrato RH et al (2014) A novel approach to fault detection and diagnosis on wind turbines. Glob Nest J 16(6):1029–1037
7. Gómez Muñoz CQ, García Márquez FP (2016) A new fault location approach for acoustic emission techniques in wind turbines. Energies 9(1):40
8. Haykin S, Network N (2004) A comprehensive foundation. Neural networks 2nd edn. Prentice Hall, Upper Saddle River
9. de la Hermosa González RR, Márquez FPG et al (2014) Pattern recognition by wavelet transforms using macro fibre composites transducers. Mech Syst Signal Process 48(1):339–350
10. de la Hermosa González RR, Márquez FPG et al (2015) Maintenance management of wind turbines structures via mfcs and wavelet transforms. Renew Sustain Energy Rev 48:472–482
11. Muñoz CQG, Marquez FPG et al (2015) In a new condition monitoring approach for maintenance management in concentrate solar plants. In: Proceedings of the ninth international conference on management science and engineering management, Springer, Heidelberg, pp 999–1008
12. de Lautour OR, Omenzetter P (2010) Damage classification and estimation in experimental structures using time series analysis and pattern recognition. Mech Syst Signal Process 24(5):1556–1569
13. Lovegrove K, Stein W (2012) Concentrating solar power technology: principles, developments and applications. Elsevier, New York

14. Marquez FPG (2006) An approach to remote condition monitoring systems management. In: Proceedings of the institution of engineering and technology international conference on railway condition monitoring, IET, pp 156–160
15. Márquez FPG, Muñoz JMC (2012) A pattern recognition and data analysis method for maintenance management. Int J Syst Sci 43(6):1014–1028
16. Márquez FPG, Pardo IPG, Nieto MRM (2015) Competitiveness based on logistic management: a real case study. Ann Oper Res 233(1):157–169
17. Márquez FPG, Pedregal DJ, Roberts C (2015) New methods for the condition monitoring of level crossings. Int J Syst Sci 46(5):878–884
18. Márquez FPG, Pérez JMP et al (2016) Identification of critical components of wind turbines using fta over the time. Renew Energy 87:869–883
19. Møller MF (1993) A scaled conjugate gradient algorithm for fast supervised learning. Neural Netw 6(4):525–533
20. Papaelias M, Cheng L et al (2016) Inspection and structural health monitoring techniques for concentrated solar power plants. Renew Energy 85:1178–1191
21. Pliego Marugán A, García Márquez FP, Pinar Pérez JM (2016) Optimal maintenance management of offshore wind farms. Energies 9(1):46
22. Prechelt L (1998) Automatic early stopping using cross validation: quantifying the criteria. Neural Netw 11(4):761–767
23. Rubinstein RY, Kroese DP (2013) The cross-entropy method: a unified approach to combinatorial optimization, Monte-Carlo simulation and machine learning. Springer, Berlin
24. Rumelhart DE, Hinton GE, Williams RJ (1985) Learning internal representations by error propagation. Tech. rep, DTIC Document
25. Rumelhart DE, McClelland JL et al (1988) Parallel distributed processing, vol 1. IEEE, MIT Press, Cambridge
26. Yu CC, Liu BD (2002) A backpropagation algorithm with adaptive learning rate and momentum coefficient. In: Proceedings of the international joint conference on neural networks, IJCNN'02. vol 2, IEEE, pp 1218–1223

Chapter 12
The Effects of Structural Equation Model's Orders on Patient Satisfaction Index

Zhihan Liu

Abstract Patient satisfaction is one of the most important tools to assess and improve the quality of healthcare services. This study is conducted to examine the effects of structural equation model's orders on patient satisfaction index by building first-order and high-order structural equation models respectively and making a comparison between them. As expected, results of empirical analysis show that the coefficients and fitting degree of high-order structural equation model are basically the same with its counterpart, suggesting the structural equation model's orders will not affect the index and play the role of simplifying the model. Besides, compared with the conventional first-order structural equation model in patient satisfaction, the high-order model tend to be an improvement, for providing the probability of analyzing intermediate latent variables and forming the theoretical basis of multi-level SEM study.

Keywords Structural equation model · Order · Patient satisfaction · Index · Evaluation

12.1 Introduction

Patient satisfaction is the primary objective of the healthcare provider innately. It gives us useful data about the structure, process and outcome of healthcare, and satisfied and dissatisfied patients have various behavioral intentions such as different level of compliancy [12]. There are common defects in the traditional multi-factor analysis methods in patient satisfaction evaluation resulted in the limitation of these methods, for instance, the lack of consideration for measuring error of psychological variables and the relatively simple setting of relationship among them, and so on. Although the traditional multivariate techniques, including multiple regression, path

Z. Liu (✉)
School of Public Administration, Central South University, Changsha 410083, People's Republic of China
e-mail: liuzhihan@csu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_12

analysis, and factor analysis, could not take into account the interaction effects among the posited variables (both dependent and independent) [7]. The Structural Equation Modeling (SEM) method put forward by Joreskog [11] in the 1970s, showed great improvement over other multivariate techniques as it can not only calculate the satisfaction, but also help to build the satisfaction index model [4]. However, it was noteworthy that although the second-order (or high-order) construct was prevalent for current SEM analyses of patient satisfaction [1, 2, 12, 17], most previous patient satisfaction models based on Chinese samples was still limited to the first-order ones [13] and they rarely mentioned the impact of models' orders on the result. As Ping [16] said, little is known about interactions involving second-order latent variables (LVs) (i.e., LVs that have other LVs as "indicators") in structural equation models. In fact, a lot of latent variables were indirectly related to observable variables through intermediary variables in patient satisfaction, which needed to be evaluated by establishing high-order structural equation model. But there haven't been enough reports about the application of high-order models in patient satisfaction in China as yet. Moreover, empirical evidence of the effects of structural equation model's orders on patient satisfaction index results was even less [14]. To figure out the problem, this study was designed to make an empirical analysis by building first-order and high-order structural equation models respectively and making a comparison between them.

12.2 Method

12.2.1 Theory of SEM

SEM is a type of Confirmatory Factor Analysis (CFA) technology. Its essence is a cause-and-effect model, containing two sub-models: Measurement Model and Structural Model. The measurement model is the external model identifying and evaluating relationships between observable variables and latent variables by the CFA approach, with the form of following matrix of regression equations:

$$X = \Lambda_x \xi + \delta, \tag{12.1}$$

$$Y = \Lambda_y \eta + \varepsilon. \tag{12.2}$$

Among them, X is observable value of the exogenous latent variable ξ, with the measurement error δ and the factor loading matrix Λ_x; Y is observable value of the endogenous latent variable η, with the measurement error ε and the factor loading matrix Λ_y.

The structural model is always referred to as the internal model that reflects the causal relationship between latent variables and. It could be expressed as the following matrix of regression equation:

$$\eta = \mathrm{B}\eta + \Gamma\xi + \zeta, \tag{12.3}$$

where ζ is residual error of the endogenous latent variable η. The regression coefficient matrix B represents the association between endogenous latent variables. The regression coefficient matrix Γ reflects the impact of the exogenous latent variable ζ on η.

12.2.2 Participants and Procedures

This study selected a regional representative and influential (with the position as a regional medical center) hospital in each part of five regions (north, south, east, west and central) in China and carried out intercept surveys at odd intervals from 2011 to 2012. A total of 501 effective questionnaires (the effective rate was 98.2 %) was finally received, complied with the sample size requirements suggested by Breckler [6].

12.2.3 Proposed Structure of Model

The Patient Satisfaction Index (PSI) model that established by this study involved 6 latent variables: "hospital identity" (Q1), "quality expectation" (Q2), "quality perception" (Q3), "value perception"(Q4), "patient satisfaction" (Q5) and "patient loyalty" (Q6). Q1 was related to 3 observable variables: "word of mouth" (Q11), "specialized characteristics" (Q12) and "therapeutic advantage" (Q13); Q2 was related to "technology" (Q21), "management" (Q22) and "general expectations" (Q23); Q4 was evaluated by "reasonable charge" (Q41); Q5 consisted of "comparison with other hospitals" (Q51) and "general satisfaction" (Q52); Q6 was related to 2 observable variables: "wish to visit again" (Q61) and "wish to recommend to kith and kin"(Q62). Q3 was explained by 13 observable variables: "waiting room order" (Q311), "symbols of facilities" (Q312), "logistics cleaning" (Q313), "registration service"(Q321), "leading examining and consulting" (Q322), "charging service" (Q323), "pharmacy" (Q324), "waiting time" (Q331), "healthcare workers' attitude" (Q332), "guiding medication" (Q333), "auxiliary examination" (Q334), "outpatient treatment" (Q335) and "symptoms improvement" (Q336).

12.3 Result

12.3.1 First-Order PSI Structural Equation Model

(1) Standardized path coefficients

By using AMOS19.0, SEM analysis was conducted to get the standardized path coefficients of the first-order PSI model created by this study, which was as shown in Fig. 12.1.

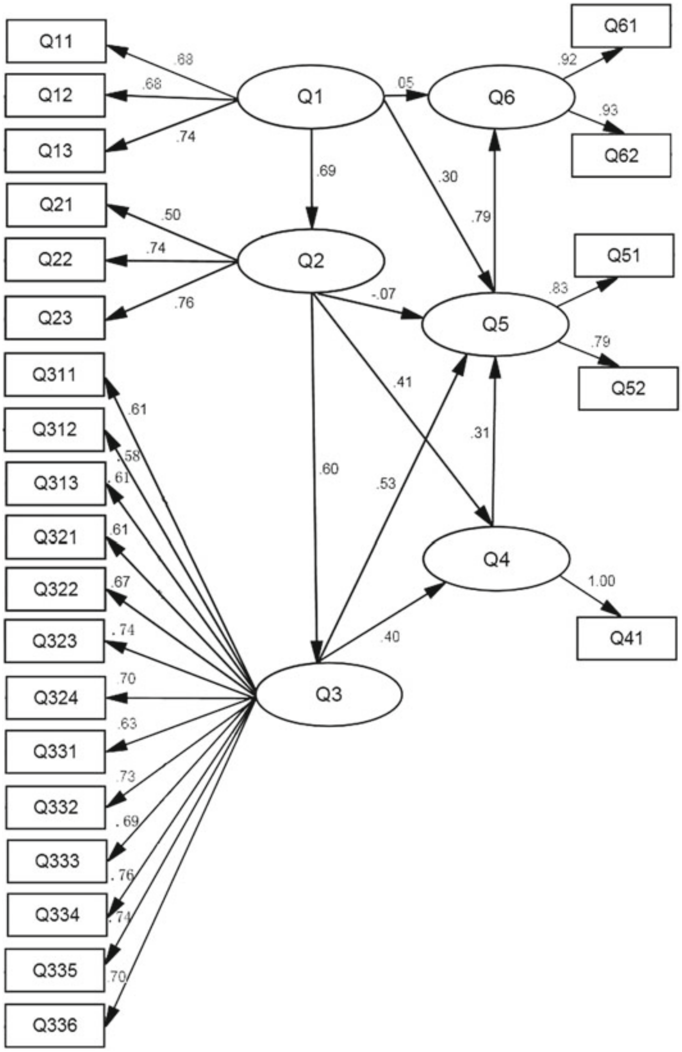


Fig. 12.1 Standardized path coefficients of the first-order PSI model

Table 12.1 The main goodness-of-fit indices for the first-order PSI model

CMIN/DF	RMSEA	GFI	AGFI	NFI	IFI	TLI	CFI
2.128	0.047	0.929	0.901	0.935	0.965	0.954	0.964

(2) Test for model fit
The common indices of model fit test were listed in Table 12.1.

It can be seen from Table 12.1, the CMIN/DF (χ^2/df) was lower than the suggested cutoff value of 3 [19], implied the acceptableness of the model. The RMSEA (root-mean-square error of approximation) is 0.047, less than the suggested value of 0.05 [18]; what's more, the values of GFI (goodness-of-fit index), AGFI (adjusted goodness-of-fit index), NFI (normed fit index), IFI (incremental fit index), TLI (Tucker-Lewis index, or "non-normed fit index (NNFI)") and CFI (comparative fit index) were all greater than the cutoff of 0.9 [5, 9], suggesting the excellence of model fit. All of the regression coefficients of the model were significant in the test ($p < 0.01$).

12.3.2 High-Order PSI Structural Equation Model

(1) Standardized path coefficients

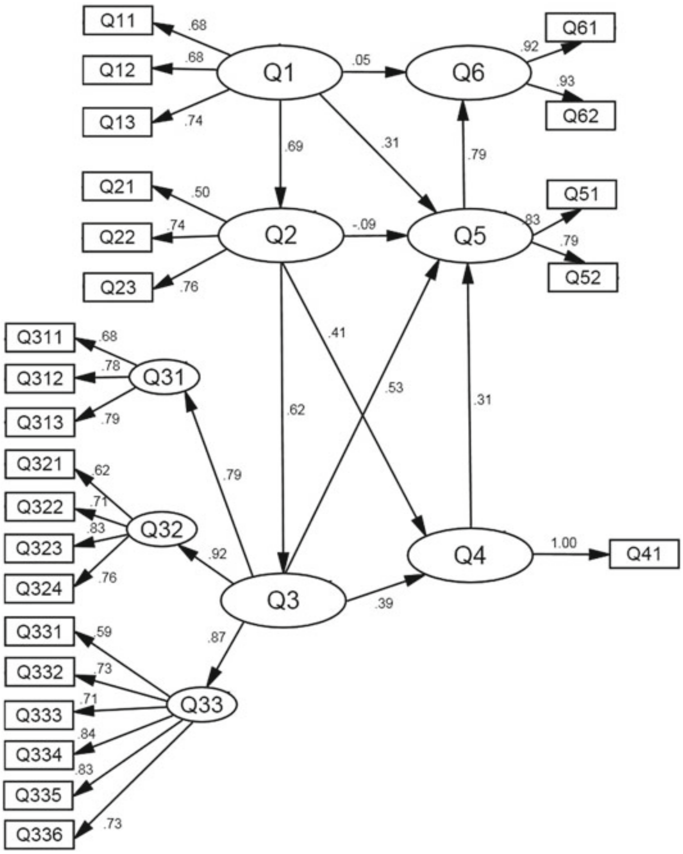


Fig. 12.2 Standardized path coefficients of the high-order PSI model

In the first-order PSI model, the 13 observed variables used to explain the latent variables "quality perception" (Q3) were referred to three different factors of assessing hospital services in actual work, i.e., "medical care environment", "ancillary services" and "medical services". Obviously, the first-order structural equation model could not reflect the differences among the three categories, thus I built the high-order structural equation model by introducing these three factors as intermediate variables: "medical environment" (Q31), "ancillary services" (Q32) and "medical service" (Q33). The standardized path coefficients of thus formed high-order PSI model was as shown in Fig. 12.2. All of the regression coefficients of the model were significant ($p < 0.01$).

(2) Test for model fit
A list of goodness-of-fit indices for the high-order model just exactly the same as it was shown in Table 12.1 was obtained through model fitting. It showed that the high-order model was reasonable and acceptable and also illustrated that the model fit degree has not been changed along with the change of orders.

12.4 Discussion

12.4.1 Comparisons for Path Coefficients and Regression Coefficients Between Models of Different Orders

It could be found from the figures above that the path coefficients of high-order model were almost consistent with the first-order model's except for several individuals differed slightly which were resulted from the computer truncation errors instead of the model itself. Besides, all the regression coefficients of observable variables of the high-order model were exactly the same with the first-order model except those correlated with the latent variable "quality perception" (Q3). The difference was led by the different hierarchical structures in this part of the two models.

12.4.2 Structural Model Analyses on Models of Different Orders

The "patient satisfaction" (Q5) was influenced by "hospital identity" (Q1), "quality expectation" (Q2), "quality perception" (Q3) and "value perception" (Q4). It was the most influential of the "quality perception", followed by the "value perception" and "hospital identity", which validated the point of view of Huo [10] that perceived quality significantly decides the customer satisfaction.

Both the high-order model and the first-order model had the same paths reflecting the positive influence of Q2 on Q3 and Q4. This result conformed with the ACSI model and validated the previous view of Fornell that customer expectation would have direct effects on quality perception and value perception [8].

In addition, the result that negative path coefficients from Q2 to Q5 were detected in both models supported the "expectation-inconsistent" theory proposed by Oliver [15].

Among the three intermediate variables that affected "quality perception", the "ancillary services" (Q32) and the "medical services" (Q33) which were more concerned by patientłspossessed greater impacts than the relatively insignificant "medical environment" (Q3). As the data analysis results were in complete accord with the actual situation, the high-order model containing nested levels of intermediate variable analyses was more powerful in clearly reflecting the impacts of different services areas on patients' quality perception.

12.4.3 Measurement Model Analyses on Models of Different Orders

As can be seen from Figs. 12.1 and 12.2, the standardized regression coefficients between observable variables and latent variables of both models were in 0.5 to 0.95 range, and all the standardized path coefficients between latent variables did not reach the cutoff of 1, conformed to the principles of parameter estimate test proposed by Bagozzi and Yi [3].

12.5 Conclusion

This study performed confirmative factors analysis of patient satisfaction index with SEM method and validated that the measuring items and the supposed cause-and-effect relationship between observable variables and latent variables were properly set.

Meanwhile, based on comparative analysis between the first-order and high-order structural equation models, the study arrived at the conclusions that the structural equation model's orders don't affect the measurement results of patient satisfaction index. Except for differences in the regression coefficients of the observed variables related to the intermediate variables, the other regression coefficients and path coefficients do not change.

Furthermore, the high-order models are generally senior than the current prevalent first-order models, for not only being able to reflect how observable variables explain the relative latent variables, but also compare and evaluate the multiple intermediate variables.

Acknowledgments This study was supported by the Project for Innovation Platform of Hunan Colleges and Universities (grant No. 15K135), Social Science Fund of Hunan Province (grant No. 15JD61) and Postdoctoral Science Foundation of Central South University (No. 153656) awarding to the author. The author declares no conflicts of interest.

References

1. Amin M, Zahora Nasharuddin S (2013) Hospital service quality and its effects on patient satisfaction and behavioural intention. Clin Govern: Int J 18(3):238–254
2. Andaleeb SS, Kara A (2014) The structure and measures of service quality perceptions for multiple-encounter services: A study of hospitals in bangladesh. Int J Healthc Manag 7(2):92–102
3. Bagozzi RP, Yi Y (1988) On the evaluation of structural equation models. J Acad Mark Sci 16(1):74–94
4. Bollen KA (2014) Structural equations with latent variables. Wiley, New York
5. Bollen KA, Long JS (1993) Testing structural equation models, vol 154. Sage, New York
6. Breckler SJ (1990) Applications of covariance structure modeling in psychology: Cause for concern? Psychol Bull 107(2):260–273
7. Cheng EW (2001) SEM being more effective than multiple regression in parsimonious model testing for management development research. J Manage Develop 20(7):650–667
8. Fornell C, Johnson MD et al (1996) The American Customer Satisfaction Index: nature, purpose, and findings. J Market 60(4):7–18
9. Hu L, Bentler PM (1999) Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct Equ Model Multidiscip J 6(1):1–55
10. Huo Y (2004) CSI Model Building and the GME Comprehensive Estimation Research of Its Parameters. Master's thesis, Doctoral Dissertation of Nanjing University of Science and Engineering
11. Jöreskog KG (1970) A general method for analysis of covariance structures. Biometrika 57(2):239–251
12. Kazemi N, Ehsani P et al (2013) Measuring hospital service quality and its influence on patient satisfaction: An empirical study using structural equation modeling. Manage Sci Lett 3(7):2125–2136
13. Lei P, Jolibert A (2012) A three-model comparison of the relationship between quality, satisfaction and loyalty: an empirical study of the chinese healthcare system. BMC Health Serv Res 12:436–477
14. Liu Z (2015) Literature review of domestic and international research on patient satisfaction. Chin J Health Policy 8(4):60–66
15. Oliver RL (1980) A cognitive model of the antecedents and consequences of satisfaction decisions. J Mark Res 17(9):460–469
16. Ping Jr A (2015) A note on estimating second-order interactions and quadratics in latent variables. In: Proceedings of the assessing the different roles of marketing theory and practice in the jaws of economic uncertainty, Springer, Berlin, pp 304
17. Qin H, Prybutok VR et al (2014) Ucperf: An urgent care patient satisfaction instrument. The Qual Manage J 21(3):11
18. Steiger JH (1989) EzPATH: A supplementary module for SYSTAT and SYSGRAPH [computer program]. SYSTAT
19. Wu M (2011) Questionnaire statistical analysis and practice–SPSS operation and application. Chongqing University Press, Chongqing

Chapter 13
Slotting Optimization of Warehousing System Based on the Hungarian Method

Yuzhen Hu, Song Zhang, Xiaojuan Jia and Jiajia Chen

Abstract This paper studies the problem of storage space optimization system based on different demand frequencies and different demand quantities. An 0–1 integer programming model is established aimed at minimizing the objective of total routing with the weight of turnover rate of the goods, based on the principle that something commonly used should be easy to take. Combining the idea of Hungarian method, the objective function and constraints are transformed, and then the problem is solved by Hungarian methods, which has been proved to get optimal solution. Finally, a data test is provided to illustrate the effectiveness of the problem. This study can provide theoretical and technical support for warehousing slotting optimization system.

Keywords Warehousing system · Slotting optimization · Hungarian algorithm · Optimal solution

13.1 Introduction

As a part of logistics system, storage plays an important role in the process of logistics integration. However, with the rapid development of modern industry, the traditional storage methods cannot meet the needs of production and circulation, and automated warehouse has been applied more and more widely. The current management of warehouse still follows the habit and experience of many years ago to store goods. It does not only waste storage space, but also degrades working efficiency of warehouse. Therefore, the location allocation problem is a very important issue in storage management system and slotting optimization has been emerged under this background.

In the face of thousands of ware location and cargo space, effective storage location assignment scheme by warehouse slotting optimization methods has become the key

Y. Hu (✉) · S. Zhang · X. Jia · J. Chen
School of Economics and Management, Harbin Engineering University,
Harbin 150001, People's Republic of China
e-mail: yuzhenhu@hrbeu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_13

factor to improve storage efficiency and cut down the warehouse cost. Furthermore, it can also significantly improve the efficiency of space using and the goods picking, removal of cargo and overcome the peak load and polish up the storage space layout.

The available literature on warehouse strategic and performance evaluation /optimization may be classified based on three main issues [1, 2]: (i) contributions to address warehouse design decisions, typically concentrating on order picking routing or product location strategies; (ii) papers to propose analytic or simulation models and (iii) publications on bench marking and performance evaluation. Slotting optimization belongs to the first issue. Koster et al. [3] thought that order picking accounts for over 40 % of the total picking time and over 65 % of the total warehousing operating cost. Therefore, reasonable slotting optimization based on picking efficiencies plays an important role in improving the efficiency of order picking in warehousing system. During space distribution, the major factors [4] that are considered include picking strategy, the feasibility of resource, warehouse maintenance and so on.

Traditional studies [5, 6] of slotting optimization focus on storage location for the highest picking efficiency. For small-scale problems, the branch and bound algorithm is generally used [7], and for large-scale problems, many intelligent algorithms, such as simulated annealing algorithm [8], and genetic algorithm [9–14], are often considered by many studies. Exploiting the SKU correlations during location assignment is to assign them to the adjacent position. Slotting optimization problem was solved by use of historical statistical correlation in much previous researches. Kim and Smith [15] found a way to generate SKUs correlation data, and proposed a slotting optimization algorithm which achieved well results. Cartonization optimization is to pack SKUs into carton. It aims to minimize the cartons and picking-walking time [3, 15]. When requiring multiple cartons, assigning SKUs which in the same carton to the adjacent location would reduce picking-walking time in possible [16, 17].

We can find that most of studies use heuristic algorithm to solve slotting optimization problem. But no study solves the problems of the optimization of the goods picking path by polynomial time algorithms. In this paper, we follow the principle that the high turnover rate of the goods should be stored close to the entrance or exits, establish 0–1 integer programming model, use the Hungarian method to solve the problem and prove that the optimal solution can be obtained.

This paper is organized as follows. In the next section, a formal description of the problem, including a statement of assumptions and constraints is given. This is followed in Sect. 13.3 by a full mathematical model. Solution methods are presented in Sect. 13.4. Section 13.5 presents the computational results. Conclusions are drawn in Sect. 13.6.

13.2 Problem Descriptions

Warehouse location optimization is to reasonably determine the proper storage allocation solution of each type of goods. The goal of Slotting optimization is to improve the work efficiency and to reduce the useless movement of the warehousing as more

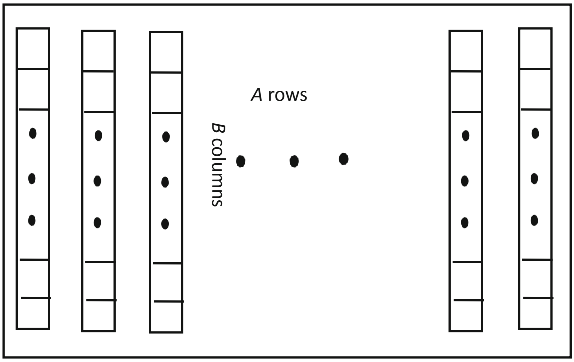


Fig. 13.1 Shelf layout

as possible by optimizing the storage system. The slotting optimization methods can help reduce storage costs and enable enterprises to obtain higher profits.

When optimizing the plane warehouse location, the major problems in this paper focus on during different period, different demand quantities and the demand frequencies will lead to different path and time of access goods in different location. At this point we should adopt the principle "something commonly used should be easy to get" to optimize the goods location, in order to improve access efficiency.

In this paper, we first calculated the time to deliver goods to the shipping port by stacker in warehouse, place the goods of higher frequency of the inbound and outbound operations in the cargo space near an exit, and store the goods of lower frequency of the inbound and outbound operations in the cargo space far away from an exit. We minimize the total time of the inbound and outbound operations of all goods, in order to improve the efficiency of warehousing system.

Given a plane warehouse, there are A rows of shelves and each shelf has B columns. We denote the row nearest the exits as row 1, the coordinate (x, y) illustrates the cargo space of row x and column y. We assume that the length and width of each cargo space is the same as L. The shelf layout is shown in Fig. 13.1.

It is assumed that there are K types of goods to be stored in the warehouse, and the turnover rate P is used to measure the inbound and outbound frequency of the goods, and the turnover rate of the goods i is P_i, and the calculation formulation of turnover rate P_i is as follows:

$$P_i = \frac{\text{total outbounds of } i}{\text{average stock of } i}, \tag{13.1}$$

$$\text{average stock of } i = \frac{\text{begining stock} + \text{end stock}}{2}. \tag{13.2}$$

During stacking machine is needed to use for the goods access procedure. It is assumed that the stacking machine can only horizontal movement and vertical movement, along the X axis direction of v_x, along the Y axis direction of the movement speed of v_y.

Other assumptions should also be given as follows.

(1) The number of goods types K has been given as a constant, and K is no more than the number of cargo spaces.
(2) the volume of each good is smaller than the capacity of the cargo space.
(3) Each location can only access a piece of goods, each kind of goods can only be stored to one location
(4) the time of accessing goods from the location is negligible, and we only consider the stacker transportation time.
(5) single exit for goods transportation.

13.3 Mathematical Formulations

A mathematical formulation model of slotting optimization is as follows, according to the assumptions and constraints in Sect. 13.2.

In order to improve the efficiency of inbound and outbound storage, it is necessary to shorten the time of storage of the goods, and it is the key to shorten the route of picking operation, that is the distance of the stacking movement for storage (the total path of the stacking machine).

In the plane warehouse, we set that the coordinates of a cargo space is (x, y), the coordinates of the exit is $(0, 0)$. As the stacker carrying goods cannot move along the straight line according to the shortest path, the distance of movement of the stacker from the cargo space to exits can be computed as follows.

$$(x + y) \times L. \tag{13.3}$$

The speed of stacker moving along the X axis direction is v_x, and the speed of stacker moving along the Y axis direction is v_y, therefore the time the stacker spending from cargo space (x, y) to exit can be computed as

$$t_{xy} = \left(\frac{x}{v_x} + \frac{y}{v_y}\right) L. \tag{13.4}$$

According to the goal of location optimization, the goods with larger turnover rate should be moved to the place near the exits and the ones with smaller turnover rate should be moved to the place far away from the exits. Therefore, the actual time it takes for the goods at (x, y) to move to the exits can be denoted as

$$t_{xy} P_i. \tag{13.5}$$

If we set binary variables D_{xyi}, then

$$D_{xyi} = \begin{cases} 1, & \text{good } i \text{ in the location } (x, y)\, 0; \\ 0, & \text{otherwise.} \end{cases} \tag{13.6}$$

Therefore, the objective function of the problem is as follows.

$$\min f = \sum\nolimits_{i=1}^{K} \sum\nolimits_{x=1}^{A} \sum\nolimits_{y=1}^{B} D_{xyi} t_{xy} P_i . \tag{13.7}$$

The constraints are as follows as well.

$$\forall i, \sum\nolimits_{x=1}^{A} \sum\nolimits_{y=1}^{B} D_{xyi} = 1, \tag{13.8}$$

$$\forall x, \forall y, \sum\nolimits_{i=1}^{K} D_{xyi} \leq 1, \tag{13.9}$$

$$D_{xyi} = \{0, 1\} . \tag{13.10}$$

Constraints (13.1) presents one piece of goods can only be located one cargo space, and Constraints (13.2) shows that one cargo space can accommodate at most one piece of goods.

13.4 Solution Methods

The Hungarian method is used to solve location optimization problem for plane warehouse system, the core idea is how to transform the concrete problem to the model that can be solved by the Hungarian algorithm, how to determine the objective function and coefficient matrix, and how to compile solution matrix. Finally the optimal solution is obtained by the Hungarian method.

13.4.1 Model Transforming

Because the Hungarian methods are used for the problem of assignment, that is, n tasks are assigned to the N individuals, and each person can only assume a task, each task can only be taken by one person, the two problems are very similar to the constraints. Therefore, provided that the slotting optimization model can be transformed to assignment problem then it can be solved by the Hungarian methods. $A \times B - K$ dummy goods are and

$$p_i = 0, i = K + 1, K = 2, \ldots, A \times B. \tag{13.11}$$

Then the slotting optimization problem has been transformed to assignment problem

Theorem 13.1 *The optimal solution stays unchanged by adding dummy goods for slotting optimization problem.*

Proof Let D_m^n be the components from row m and column n in the matrix of D_{xyi}. It is assumed that D_1^K is the optimal solution of slotting optimization problem. For each feasible solution F_1^K, then we have

$$D_1^K \times \left(t_{xyi} P_i\right)_1^K < F_1^K \times \left(t_{xyi} P_i\right)_1^K . \tag{13.12}$$

As the objective function of the model presents the sum of the product of two elements in matrixes $D_1^{A\times B}$ and $\left(t_{xyi} P_i\right)_1^{A\times B}$, then we obtain that

$$D_1^{A\times B} = \begin{bmatrix} D_1^K \\ D_{K+1}^{A\times B} \end{bmatrix}; \left(t_{xyi} P_i\right)_1^{A\times B} = \begin{bmatrix} (t_{xyi} P_i)_1^K \\ (t_{xyi} P_i)_{K+1}^{A\times B} \end{bmatrix}, \tag{13.13}$$

$$\begin{aligned} D_1^{A\times B} \times \left(t_{xyi} P_i\right)_1^{A\times B} &= \begin{bmatrix} D_1^K \\ D_{K+1}^{A\times B} \end{bmatrix} \times \begin{bmatrix} (t_{xyi} P_i)_1^K \\ (t_{xyi} P_i)_{K+1}^{A\times B} \end{bmatrix} \\ &= D_1^K \times (t_{xyi} P_i)_1^K + D_{K+1}^{A\times B} \times (t_{xyi} P_i)_{K+1}^{A\times B}. \end{aligned} \tag{13.14}$$

As $P_i = 0, i = K+1, K+2, \ldots, A\times B$, so

$$D_{K+1}^{A\times B} \times \left(t_{xyi} P_i\right)_{K+1}^{A\times B} = 0, \tag{13.15}$$

$$F_{K+1}^{A\times B} \times \left(t_{xyi} P_i\right)_{K+1}^{A\times B} = 0. \tag{13.16}$$

And for each feasible solution after transforming, we get

$$\begin{aligned} D_1^K \times \left(t_{xyi} P_i\right)_1^K + D_{K+1}^{A\times B} \times \left(t_{xyi} P_i\right)_{K+1}^{A\times B} &= D_1^K \times \left(t_{xyi} P_i\right)_1^K \\ &< F_1^K \left(t_{xyi} P_i\right)_1^K + F_{K+1}^{A\times B} \times \left(t_{xyi} P_i\right)_{K+1}^{A\times B} \\ &= F_1^{A\times B} \times \left(t_{xyi} P_i\right)_1^{A\times B} . \end{aligned} \tag{13.17}$$

From the above proof we get that adding dummy goods have no impact on the optimal solution.

13.4.2 Objective and Constraints Transforming

From formulation (13.11) we get

$$\sum\nolimits_{i=K+1}^{A\times B}\sum\nolimits_{x=1}^{A}\sum\nolimits_{y=1}^{B} D_{xyi}t_{xy}P_i = 0. \tag{13.18}$$

So the objective function (13.7) can be described as follows.

$$\begin{aligned}
\min f &= \sum\nolimits_{i=1}^{K}\sum\nolimits_{x=1}^{A}\sum\nolimits_{y=1}^{B} D_{xyi}t_{xy}P_i \\
&= \sum\nolimits_{i=1}^{K}\sum\nolimits_{x=1}^{A}\sum\nolimits_{y=1}^{B} D_{xyi}t_{xy}P_i + \sum\nolimits_{i=K+1}^{A\times B}\sum\nolimits_{x=1}^{A}\sum\nolimits_{y=1}^{B} D_{xyi}t_{xy}P_i \\
&= \sum\nolimits_{i=K+1}^{A\times B}\sum\nolimits_{x=1}^{A}\sum\nolimits_{y=1}^{B} D_{xyi}t_{xy}P_i \\
&= \sum\nolimits_{i=1}^{A\times B}(\sum\nolimits_{x=1}^{A}\sum\nolimits_{y=1}^{B})D_{xyi}(t_{xy}P_i).
\end{aligned} \tag{13.19}$$

And constraints (13.9) can also be edited as follows.

$$\forall x, \forall y, \sum\nolimits_{i=1}^{K} D_{xyi} = 1 \tag{13.20}$$

13.4.3 Coefficient Matrix

The coefficient matrix is composed of $(t_{xy}P_i)$, $\forall x, \forall y, \forall i$, Then the matrix is shown in Table 13.1.

Table 13.1 Coefficient matrix for slotting optimization

	t_{11}	t_{12}	$\cdots$	t_{xy}	$\cdots$	t_{AB}
P_1	$t_{11}P_1$	$t_{12}P_1$	$\cdots$	$t_{xy}P_1$	$\cdots$	$t_{AB}P_1$
P_2	$t_{11}P_2$	$t_{12}P_2$	$\cdots$	$t_{xy}P_2$	$\cdots$	$t_{AB}P_2$
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
P_K	$t_{11}P_K$	$t_{12}P_K$	$\cdots$	$t_{xy}P_K$	$\cdots$	$t_{AB}P_K$
P_K+1	$t_{11}P_{K+1}$	$t_{12}P_{K+1}$	$\cdots$	$t_{xy}P_{K+1}$	$\cdots$	$t_{AB}P_{K+1}$
$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$	$\cdots$
$P_A\times B$	$t_{11}P_{A\times B}$	$t_{12}P_{A\times B}$	$\cdots$	$t_{xy}P_{A\times B}$	$\cdots$	$t_{AB}P_{A\times B}$

Table 13.2 Coefficient matrix for slotting optimization

	(1, 1)	(1, 2)	⋯	(x, y)	⋯	(A, B)	SUM
1	–	–	–	–	–	–	1
2	–	–	–	–	–	–	1
⋯	–	–	–	–	–	–	1
m	–	–	–	–	–	–	1
$m+1$	–	–	–	–	–	–	1
⋯	–	–	–	–	–	–	1
$A \times B$	–	–	–	–	–	–	1
SUM	1	1	1	1	1	1	–

13.4.4 Compilation of Solution Matrix

The solution of slotting optimization is composed of matrix D_{xyi} of $A \times B$ rows and $A \times B$ columns. For easy analysis of constraints and optimal results, we first give an empty matrix of $A \times B$ rows and $A \times B$ columns in Table 13.2, and then insert optimal solution into the matrix.

13.4.5 Algorithm

The Hungarian algorithm is described as follows.

Step 1. To transform the matrix $\left(t_{xy}P_i\right)_{A\times B\times(A\times B)}$ until There is 0 element in each column and each row

Step 2. Try to assign the matrix and seek the optimal solution. If the number of independent 0 in the matrix is $A \times B$, then the components of the location in the solution matrix corresponding to 0 in the coefficient matrix will be set 1 and other components will be set 0. If the number of independent 0 in the matrix is less than $A \times B$, then we will seek them by the following ways.

- **Step 2.1** begin from the row (or column) where there is only one 0 component, give mark "⊚" to the component, and delete other 0 components in the column (or row) that contain the 0 components marked by "⊚" and mark them "Φ".
- **Step 2.2** give mark "⊚" to the 0 components in the column (or row) where there is only one 0 component and delete other 0 components in the row (or column) that contain the 0 component marked by "⊚" and mark them "Φ".
- **Step 2.3** implement Step 2.1 and Step 2.2 until all 0 components are marked by "Φ" or "⊚".

Step 2.4 if the number of 0 components which are marked by "◎" is $A \times B$, then optimal solution has been found and to Step 5. If m $< A \times B$, then to Step 3.

Step 3. Use the fewest number of lines to cover all components through the following ways.

Step 3.1 mark the rows without 0 components marked by "◎" by $\surd$;
Step 3.2 mark the columns containing 0 components marked by "Φ" in the rows marked by $\surd$ by $\surd$;
Step 3.3 mark the rows with 0 components marked by "◎" in the columns marked by $\surd$ by $\surd$;
Step 3.4 repeat Step 3.2 and Step 3.3 until no row or column should be marked;
Step 3.5 each row not marked by $\surd$ and each column marked by $\surd$ will be covered by a line. The number of lines is denoted as l. If l $<$ $A \times B$, then to Step 4; if l $= A \times B$ and m $< A \times B$, then proceed to Step 2.;

Step 4. Seek for the minimum component in the matrix part not covered by lines, and each row marked by $\surd$ subtracts the minimum component and each column marked by $\surd$ adds the minimum component to get a new coefficient matrix. If there are $A \times B$ independent 0 components in the new matrix, then to Step 5; otherwise to Step 3;
Step 5. Output the optimal solution.

Theorem 13.2 *The solution matrix got from the Hungarian algorithm is optimal.*

Proof The major work in the Hungarian algorithm is elementary transformation for the coefficient matrix. The minimum component from each row and each column is subtracted and 0 component is made to display in each row and each column. It is assumed that in coefficient matrix $\left(t_{xy}P_i\right)_{A\times B\times(A\times B)}$, a constant a is subtracted for each component in row I and a constant b is subtracted for each component in column j. Then a new coefficient matrix $\left(t_{xy}P_i\right)'_{A\times B\times(A**B)}$ is obtained. The new objective function is

$$\begin{aligned} f' &= \sum_{i=1}^{A\times B}\sum_{x=1}^{A}\sum_{y=1}^{B} D_{xyi}\left(t_{xy}P_i\right)' = \sum_{i=1}^{A\times B}\sum_{x=1}^{A}\sum_{y=1}^{B} D_{xyi}t_{xy}P_i - a\sum_{x=1}^{A}\sum_{y=1}^{B} D_{xyi} - b\sum_{i=1}^{A*B} D_{xyi} \\ &= \sum_{i=1}^{A\times B}\sum_{x=1}^{A}\sum_{y=1}^{B} D_{xyi}t_{xy}P_i - a - b. \end{aligned} \tag{13.21}$$

From formulation (13.21), we know that both the new objective function and the old objective function have the same optimal solution and the difference of them is the objective value.

13.5 Computational Simulation

13.5.1 Data Set

We extract a part of the cargo area of the warehouse in a Business Company as sampled data, and $A = 3$, $B = 3$, $L = 1$ m, $v_x = v_y = 1$ m/s, and the time of picking goods is Negligible. 5 types of goods are located in the cargo spaces. We give the information of goods including the item numbers, turnover rate P_i, and the coordinate of initial storage position in Table 13.3 (Table 13.4).

13.5.2 Simulation Result

According to the data set provided in Sect. 13.5.1, and the solution method shown in Sect. 13.4, we give the coefficient matrix in Table 13.5 and solution matrix in Table 13.6.

From Table 13.6, we know that the optimal solution is D_{115}, D_{124}, D_{213}, D_{311}, and D_{222} equals to 1 and other D_{xyi} all equal to 0. To illustrate the cargo space assignment more visually, we give a check pane of 3×3 and use the different colors to express goods with different turnover rates. Deep color refers to goods with higher turnover rate and light color refers to goods with lower turnover rate. Figure 13.2 gives initial space assignment and Fig. 13.3 gives the improvement by our methods.

From the two figures, we know that the initial moving time is

$$F = 0.3 \times 2 + 0.2 \times 4 + 0.6 \times 4 + 0.5 \times 4 + 0.8 \times 6 = 10.6.$$

Table 13.3 Information of goods for sampled data

Item no.	Pi	Initial coordinate
1	0.3	(1, 1)
2	0.2	(1, 3)
3	0.6	(2, 2)
4	0.5	(3, 1)
5	0.8	(3, 3)

Table 13.4 Moving time to exit

Cargo spaces	(1, 1)	(1, 2)	(1, 3)	(2, 1)	(2, 2)	(2, 3)	(3, 1)	(3, 2)	(3, 3)
t_{xy}	2	3	4	3	4	5	4	5	6

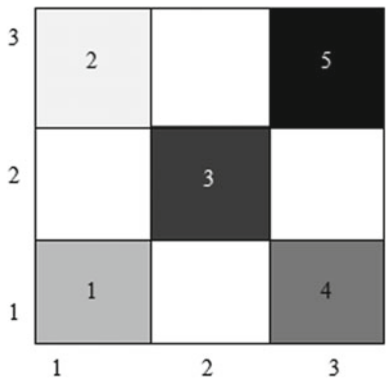
Table 13.5 Coefficient matrix

	2	3	3	4	4	4	5	5	6
0.3	0.6	0.9	0.9	1.2	1.2	1.2	1.5	1.5	1.8
0.2	0.4	0.6	0.6	0.8	0.8	0.8	1	1	1.2
0.6	1.2	1.8	1.8	2.4	2.4	2.4	3	3	3.6
0.5	1	1.5	1.5	2	2	2	2.5	2.5	3
0.8	1.6	2.4	2.4	3.2	3.2	3.2	4	4	4.8
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

Table 13.6 Coefficient matrix

	(1, 1)	(1, 2)	(2, 1)	(2, 2)	(1, 3)	(3, 1)	(2, 3)	(3, 2)	(3, 3)	SUM
1	0	0	0	0	0	1	0	0	0	1
2	0	0	0	1	0	0	0	0	0	1
3	0	0	1	0	0	0	0	0	0	1
4	0	1	0	0	0	0	0	0	0	1
5	1	0	0	0	0	0	0	0	0	1
6	0	0	0	0	1	0	0	0	0	1
7	0	0	0	0	0	0	0	0	1	1
8	0	0	0	0	0	0	1	0	0	1
9	0	0	0	0	0	0	0	1	0	1
SUM	1	1	1	1	1	1	1	1	1	

Fig. 13.2 Initial space assignment



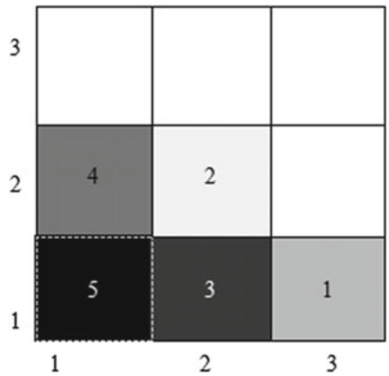


Fig. 13.3 Initial space assignment

After improvement by the Hungarian algorithm, the goods with higher turnover rate have been located in the space near exits and goods with lower turnover rate have been located in the space far away from exits. The moving time is

$$f = 0.8 \times 2 + 0.6 \times 3 + 0.5 \times 3 + 0.3 \times 4 + 0.2 \times 4 = 6.9.$$

the saved time is $F - f = 3.7$.

13.6 Conclusion

This paper focuses on slotting optimization problem of plain warehouse system, based on different turnover rates of goods. A detailed formal description for the problem is first given, and some factors affecting on cargo space assignment of plain warehouse system are then analyzed. Finally an integer programming model is constructed.

A logical equivalent transformation is adopted from an integer programming model to the model that can be solved by the Hungarian algorithm. A dataset test illustrates the effectiveness of the method presented in this paper.

In the future, it would be worthwhile to examine several related issues. Firstly, the volumes of different types of goods vary greatly, therefore volume difference should be considered when optimizing the warehousing storage. Secondly, if it were possible to develop an expanded model that describes the tridimensional warehouse, improved results would likely follow. Finally, other solution approaches, such as meta-heuristics or robust optimization might prove advantageous for some large scale slotting optimization problem. Although we were able to find optimal solutions for the instance examined, stable solutions are more often preferred by practitioners.

Acknowledgments This paper is supported by the project of Provincial Natural Science Foundation (JJ2016QN0048) the project of Central University Basic Research Fund (HEUCF150903), the project of Provincial Postdoctoral Fund (LBH-Z15047), the National Natural Science Foundation of China(71401162).

References

1. Gu J, Goetschalckx M, McGinnis LF (2010) Research on warehouse design and performance evaluation: a comprehensive review. Eur J Oper Res 203(3):539–549
2. Johnson A, McGinnis L (2010) Performance measurement in the warehousing industry. IIE Trans 43(3):220–230
3. Koster D, Le-Duc T et al (2007) Design and control of warehouse order picking: a literature review. Eur J Oper Res 182(2):481–501
4. Yan Y, Sun X, Pan E (2000) Some discussion on the relation between shelves number and stacker operating efficiency in stereo warehouse. Ind Eng Manag 5:29–33
5. Brynzér H, Johansson MI (1996) Storage location assignment: using the product structure to reduce order picking times. Int J Prod Econ 46:595–603
6. Muppani VR, Adil GK (2008a) A branch and bound algorithm for class based storage location assignment. Eur J Oper Res 189(2):492–507
7. Muppani VR, Adil GK (2008b) A branch and bound algorithm for class based storage location assignment. Eur J Oper Res 189(2):492–507
8. Wang Z, Lin J et al (1996) Order picking optimization for a multicarousel-single-server system solved by improved annealing procedure. Controls Decis 11(7):182–187
9. Lin JH, Li GF, Li JX (1997) Multi-carousel with two servers. J Shandong Univ Technol 27(3):236–239
10. Jin M, Mu X et al (2015) A cellular ant algorithm-based method for solving stereo warehouse slotting optimization problem. In: Proceedings of China Modern Logistics Engineering, Springer, pp 273–282
11. Liu S, Ke Y, Li J (2006) Optimization for automated warehouse based on scheduling policy. Comput Integr Manuf Syst-Beijing 12(9):14–38
12. Ma Y, Li Z, Yun W (2015) Fast genetic algorithm for pick-up path optimization in the large warehouse system. In: Advances in swarm and computational intelligence, Springer, pp 38–44
13. Zhang P, Tian GH et al (2004) New hybrid genetic algorithm solving the order-picking optimization problem of a multi-carousel system. Chin J Mech Eng 40(6):34–38
14. Poulos P, Rigatos G et al (2001) A pareto-optimal genetic algorithm for warehouse multi-objective optimization. Eng Appl Artif Intell 14(6):737–749
15. Kim B, Smith J (2008) Dynamic slotting for zone-based distribution center picking operation. 10th International material handling research colloquium. Dortmund, Germany, pp 577–599
16. Bonassa AC, Cunha CB (2011) The order-picking routing problem for low-level order picker in a warehouse. Gestão Produção 18(1):105–118
17. Henn S, Schmid V (2013) Metaheuristics for order batching and sequencing in manual order picking systems. Comput Ind Eng 66(2):338–351

Chapter 14
Study of Mutual Relations of Transition Characteristics of Elementary Links with a View to Automatic Structural Identification

Fazil Azin Oglu Alekperli and Mammad Ali Oglu Shabanov

Abstract Mutual relations of the dynamic characteristics of the elementary links of automatic control system that are verified by the theorems proved in the paper are considered. These relations of dynamic characteristics of elementary links allow to create the algorithms of automatic identification of the structure of the control object that are given in the paper for deterministic and noisy objects.

Keywords Transitive characteristic · Transfer function · Control object · Dynamic model · Automatic identification structure · Parametric identification

14.1 Introduction

At design of automatic regulation systems one of the steps is identification of dynamic models (the transfer functions) of an object. There are different methods of parametric identification of dynamic models of control objects of the known structure [4–9]. Among the methods of identification of the transfer functions the graphic analytical methods using transient response of the control object have special mean [4, 8]. Graphic-analytical methods being manual execution of identification procedures allow estimating parameters of the transfer function at the known its structure. The model structure is determined by a researcher by kind of the transient characteristic or by using additional tables [7], i.e., the algorithms automatically determination of an object structure are not. In this paper an algorithm for automatically identification of structure of the regulation object connected with computer is offered, for example, with controller by measurement and control channels.

F.A. Oglu Alekperli (✉) · M.A. Oglu Shabanov
Sumgait State University, Sumqayit, Azerbaijan
e-mail: fazlf_50@mail.ru

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_14

14.2 Mutual Relation of the Transitional Characteristics of the Link Parts

The transitional characteristics of the dynamical link parts are described by the following equation [3]:

The amplifying link

$$h_1(t) = K \cdot 1(t).$$

The integrating link

$$h_2(t) = \frac{K}{T_u} t \cdot 1(t).$$

The inertia link (aperiodic of first order)

$$h_3(t) = K\left(1 - e^{-\frac{t}{T}}\right) \cdot 1(t).$$

The aperiodic link of second order

$$h_4(t) = K\left(1 + C_1 e^{-\alpha_1 t} - C_2 e^{-\alpha_2 t}\right) \cdot 1(t);$$
$$\alpha_1 = \frac{1}{T_1}; \ \ \alpha_2 = \frac{1}{T_2}; \ \ C_1 = \frac{T_1}{T_2 - T_1}; \ \ C_2 = \frac{T_2}{T_2 - T_1}.$$

The oscillate link

$$h_5(t) = K\left(1 - \frac{1}{\omega_m \cdot T} e^{-\frac{\xi}{T} t} \sin(\omega_m t + \phi)\right) \cdot 1(t); \ \ \omega_m = \frac{\sqrt{1-\xi^2}}{T}$$
$$\phi = \operatorname{arctg} \frac{\omega_m T}{\xi}.$$

The inertia-integrating link

$$h_6(t) = K\left(t - T\left(1 - e^{-\frac{t}{T}}\right)\right) \cdot 1(t).$$

Let's, the transitional characteristics $h_1(t)$, $h_3(t)$, $h_4(t)$, $h_5(t)$ get practically right value K for T_u time, and the transitional characteristics $h_2(t)$, $h_6(t)$ at moment of T_u time cross a horizontal line with high K.

Theorem 14.1 *The characteristic of aperiodic link of first order $h_3(t)$ in an interval $(0, T_u)$ is between characteristics of amplifying $h_1(t)$ and the integrated $h_2(t)$ links.*

Proof it is from the theorem that, terms must be executed.

$$h_1(t) > h_3(t) \quad \text{and} \quad h_3(t) > h_2(t)$$

or

$$\Delta h_{1,3}(t) = h_1(t) - h_3(t) > 0 \quad \text{and} \quad \Delta h_{2,3}(t) = h_3(t) - h_2(t) > 0$$

in interval $(0, T_u)$.

The function of $\Delta h_{1,3}(t) = K \cdot e^{-\frac{t}{T}} 1(t) > 0$ at $t > 0$ and positive values K and T.

The function of $\Delta h_{2ç3}(t) = K\left[\left(1 - e^{-\frac{t}{T}}\right) - \frac{1}{T_u}t\right] \cdot 1(t)$ is protuberant in interval $(0, T_u)$ and it is enough to prove that it is positive on some point t_1 of this interval. As such point we take $t_1 = T$. It is not difficult to prove that $T_u > 3T$. Taking into account said $\Delta h_{2,3}(T) > K\left(0,632 - \frac{T}{3T}\right) \cdot 1(t) > 0$.

Theorem 14.2 *The characteristic of aperiodic link of second order $h_4(t)$ always being below than the characteristic of amplifying link $h_1(t)$, in the beginning interval $(0, T_u)$ is below than the characteristics of the integrated link $h_2(t)$, and further higher than it.*

Proof The conditions of the theorem must be executed $h_4(t) < h_1(t)$ in interval $(0, T_u)$, $h_4(t) < h_2(t)$, $h_4(t) < h_2(t)$, in interval $(0, t_p)$ and $h_4(t) > h_2(t)$ in interval (t_p, T_u), where t_p abscise of point intersections of characteristics $h_2(t)$ and $h_4(t)$. These conditions like other view can write:

$\Delta h_{1,4}(t) = h_1(t) - h_4(t) > 0$ in interval $(0, T_u)$;

$\Delta h_{2,4}(t) = h_4(t) - h_2(t)$ and $\Delta h_{2,4}(t) < 0$ in interval $(0, t_p)$, $\Delta h_{2,4}(t) > 0$ in interval (t_p, T_u).

Function $\Delta h_{1,4}(t) = K(C_1 e^{-\alpha_1 t} - C_2 e^{-\alpha_2 t}) \cdot 1(t) > 0$ at all values T_1 and T_2, except value $T_1 = T_2$.

For checking the condition $\Delta h_{2,4}(t) < 0$ in interval $(0, t_p)$ it is enough to show that derivative its less than zero in point $t = 0$, that is $\Delta h'_{2,4}(0) < 0$. Really, $\Delta h'_{2,4}(t) = -K(\frac{1}{T_u} - \alpha_1 C_1 e^{-\alpha_1 t} + \alpha_2 C_2 e^{-\alpha_2 t}) \cdot 1(t)$ and $\Delta h'_{2,4}(0) = -K\frac{1}{T_u} \cdot 1(0) < 0$ at all values K.

For checking the condition $\Delta h_{2,4}(t) < 0$ in interval (t_p, T_u) it is enough to show, that its deriving in less than zero in a point $t = T_u$, that is $\Delta h'_{2,4}(T_u) < 0$. It is known that transitional characteristics of links or regulation system get its balance values theoretically at $T_u = \infty$. Therefore instead of condition $\Delta h'_{2,4}(T_u) < 0$ we will check a condition $\Delta h'_{2,4}(\infty) < 0$. Actually $\Delta h'_{2,4}(\infty) = -0$. Sign minus before a zero means that function $\Delta h_{2,4}(t)$ is decreasing to the point $T_u = \infty$.

Theorem 14.3 *Characteristic of oscillating link $h_5(t)$ only in the initial moment of interval $(0, T_u)$ is below than characteristic of integrating link $h_2(t)$, further higher its and hesitates round characteristic of amplifying link $h_1(t) = K$.*

Proof The function $\Delta h_{2,5}(0) = h_5(0) - h_2(0)$ uses. For executing the condition $h_5(t) < h_2(t)$ at the beginning interval $(0, T_u)$ is enough that $\Delta h'_{2,5}(0) < 0$. Really the function

$$\Delta h'_{2,5}(t) = K(\frac{1}{\omega_m T^2} e^{-\frac{\xi}{T}t} \sin \omega_m t - \frac{1}{T_u}) \cdot 1(t) = -K \frac{1}{T_u} 1(0)_{t=0} < 0$$

at positives values of the oscillating link.

Characteristic of the oscillating link crosses the characteristic $h_1(t) = K$ in point with abscissas $t = \frac{1}{\omega_m}$ arctg $(-\frac{T\omega_m}{\xi}) + \pi$ [3].

Theorem 14.4 *Characteristic of inversion-integrated link* $h_6(t)$ *in interval* $(0, T_u)$ *is lower the characteristic of amplifying* $h_1(t)$ *and integrated* $h_2(t)$ *links.*

Proof By conditions of the theorem $h_1(t) > h_6(t)$ and $h_2(t) > h_6(t)$ must execute or $\Delta h_{1,6}(t) = h_1(t) - h_6(t) > 0$ and $\Delta h_{2,6}(t) = h_6(t) - h_2(t) < 0$ in interval $(0, T_u)$.

Really, $\Delta h_{1,6}(t) = K\left\{1 - \frac{1}{T_u - T}\left[t - T\left(t - e^{-\frac{t}{T}}\right)\right]\right\} 1(t) > 0$ at positive values K, T and $0 < t < T_u$ (theoretically $T_u = \infty$). Concavity of the function $\Delta h_{2,6}(t) = \left\{K\left[t - T\left(1 - e^{-\frac{t}{T}}\right) - t\right]\right\} 1(t)$ means satisfying with the condition $\Delta h_{2,6}(t) < 0$. For concavity of that function its second derivative must be positive in interval $(0, T_u)$. This condition also executes as $\Delta h''_{2,6}(t) = \frac{K}{T} e^{-\frac{t}{T}}.1(t) > 0$ at positive values t, T and K.

14.3 Algorithm of Structural Identification

Algorithm of automatically identification of the structure is presented as follows. It is assumed that the multidimensional object of regulation connected to the computing device (CD), for example, to the computer or controller on the channels of measuring and management. Every channel of object can have one of the above enumerated transitional characteristics.

Identification is begun from collection of information. At implementation of necessary terms of active experiment [8] CD gives a trial signal Δx as a single jump on the entrance of the chosen channel of object and gets from the exit of the same channel the sequence of numbers with time interval $T << T_k$, where T_k is the discretization interval determined by the theorem of Kotelnikova–Shennona [5]. Collection of information proceeds till implementation of condition

$$\begin{aligned} \tilde{y}[iT] - \tilde{y}[(i+1)T] &= \tilde{y}[(i+1)T] - \tilde{y}[(i+2)T] \\ &= \cdots = \tilde{y}[(i+l)T] - \tilde{y}[(i+l+1)T]. \end{aligned} \tag{14.1}$$

The balanced value of transition characteristic is $\tilde{y}[iT], l > 1$-integer, defines preliminary. Thus, the first numbering sequence of the transit characteristic of channel of the object has a view:

$$\tilde{Y} = (\tilde{y}[0T], \tilde{y}[1T], \ldots, \tilde{y}[iT]).$$

By means of the expression

$$\bar{Y}[kT] = \frac{\tilde{y}[kT] - \tilde{y}[0T]}{\Delta x \cdot \tilde{y}[iT]}, \ (k = 0, 1, \ldots, i),$$

from the sequence $\tilde{Y}$ the following sequence gets

$$\bar{Y} = (\bar{y}[0T], \ \bar{y}[1T], \ldots, \bar{y}[iT]).$$

Further delay of object $\tau = (\lambda - 1)T$, where λ- number of zero's elements in the beginning sequences $\bar{Y}$. From beginning sequences $\bar{Y}$ the zero's elements are dilated $\bar{y}[0T], \bar{y}[1T], \ldots, \bar{y}[(\lambda - 1)T]$, finale quantity sequences is got

$$Y = \{y[0T], y[1T], y[2T], \ldots, y[rT]\}, \tag{14.2}$$

which is presented as transitional characteristic of object channel without a delay. Graphic of accordance between sequences Y and $\bar{Y}$: $Q = \{(y[iT], \bar{y}[(\lambda + i)T]), i = 0, 1, \ldots, r\}$

By a value $y[rT]$ sequences accordance transits characteristics of amplifying and integrating links are formed:

$$Y_1 = (y_1[0T], y_1[1T], y_1[2T], \ldots, y_1[rT]), \ \ y_1[iT] = y_1[rT], \quad i = 0, 1, \ldots, r, \tag{14.3}$$

$$Y_2 = (y_2[0T], y_2[1T], y_2[2T], \ldots, y_2[rT]), \quad y_2[iT] = \frac{i}{r} y[rT], \ \ i = 0, 1, \ldots, r \tag{14.4}$$

By using the mutual relations of transitional characteristics, by means of sequences Eqs. (14.2)–(14.4), by the method of exception, structural identification is existed in the following stages:

(1) Condition $Y - Y_1 = 0$, where the executed that is channel has salutatory transits characteristic, that is optioned transmission function of amplifying link, is checking;
(2) Condition $Y - Y_2 = 0$, where the executed that is channel has linear increasing transits characteristic, that is optioned transmission function of integrating link, is checking;
(3) Except initial and eventual values of sequences Eqs. (14.2)–(14.4), $Y_1 > Y > Y_2$ condition is checked up. Implementation of condition means that a channel has monotonous protuberant upwards transitional characteristic, that is the transmission function of aperiodic link of first order gets out;

(4) Except initial and eventual values of sequences Eqs. (14.2)–(14.4), $Y_1 > Y$ and $Y_2 > Y$ conditions are checked up. Implementations of conditions mean that a channel has monotonous protuberant downward transitional characteristic, that is the transmission function of inertia integrating link gets out;

(5) Except initial and eventual values of sequences Eqs. (14.2)–(14.4), conditions are checked up: $Y_1 > Y$; $Y_2 > Y$ in first and $Y > Y_2$ in rest of sequences of Eqs. (14.2) and (14.4). Implementation of conditions means that a channel has S-transitional characteristic. Further condition $\frac{t_b}{t_a} \leq 1.4$ is checked up, where the executing means that channel has characteristic of a periodical link of second order, otherwise link is higher than the second order. In a case of getting link of higher order, view of the model defines as iterative on the stage of parametrical identification by criterions of adequacy. Values t_a and t_b at calculation of identification it is defined from transition characteristic, as shown in the Fig. 14.1. Line is tangent of transitional description in an inflection point d, where the flexion of characteristic has a zero value, more left—positive, and more right—negative values. At automatic implementation these values are determined on expressions

$$t_a = \frac{y[rT] - y_d}{y[kT] - y_d}\frac{T}{2},$$
$$t_b = \frac{y(rT)}{y(kT) - y_d}\frac{T}{2},$$
$$y_d = \frac{y[kT] + y[(k-1)T]}{2}.$$

An inflection point is determined by a search on the change of sign of flexion. $y[kT]$ is the first element of sequence Eq. (14.2), where the sign of flexion of transitional characteristic is negative and determined by expression:

$$\text{sign}\,(y''(iT)) = \frac{y((i+1)T) - 2y(iT) + y((i-1)T)}{T^2}, \, (i = 1, 2, \ldots).$$

(6) Condition $Y > Y_2$ and shake Y around Y_1 implementation of that means that the channel of object has a shake transitional characteristic are checked up. An order and type of model are determined iterative on the stage of self-reactance authentication.

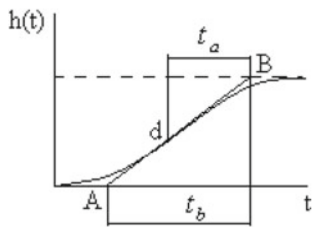


Fig. 14.1 For definition of values t_a and t_b

(7) The channel of object has transitional characteristic that is differed of the higher considered descriptions.

It should be noted that above the given algorithm of structural authentication is just for the determined objects. The real objects are not determined, and at measuring an useful signal is distorted by noises of different family. For application of the described algorithm for the real objects measuring results are filtered, and then the structure of object is determined as follows:

(1) A condition $|Y - Y_1| \leq \sigma$, where implementation means that a channel has saltatory transitional description is checked up, that is the transmission function of amplifying link is optioned;
(2) A condition $|Y - Y_2| \leq \sigma$, where implementation means that a channel has arc-wise increasing transitional description is checked up, that is the transmission function of integrating link is optioned;
(3) Except initial and eventual values of sequences Eqs. (14.2) and (14.4), condition $Y_1 + \sigma \geq Y \geq Y_2 - \sigma$ is checked up. Implementation of condition means that a channel has monotonous protuberant upwards transitional characteristic, that is transmission function of aperiodic link of first-order is optioned;
(4) Except initial and eventual values of sequences Eqs. (14.2) and (14.4) condition $Y_2 + \sigma \geq Y$ is checked up. Implementation of condition means that a channel has monotonous protuberant downward transitional characteristic, that is transmission function of inertia-integrating link gets out;
(5) Except initial and eventual values of sequences Eqs. (14.2) and (14.4), conditions $|Y_1 + \sigma \geq Y|$; $|Y_2 + \sigma \geq Y|$ in the first and $Y \geq Y_2 - \sigma$ in other the parts of the sequence are checked up: Eqs. (14.2) and (14.4). Implementations of conditions means, that a channel has S - form transitional characteristic. Order and type of the model on the stage of self-reactance authentication are determined as iterative, since the transmission function of aperiodic link the second order;
(6) Condition $Y \geq Y_2 - \sigma$ and shake Y round Y_1, where implementation of that means that the channel of object has a shake transitional description, are checked up. Order and type of model on the stage of self-reactance authentication are determined as iterative, since the transmission function of a shake link;
(7) The channel of object has transitional characteristic different from the higher considered characteristics.

14.4 Conclusions

The proposed algorithms based on the relationship of transient characteristics of the elementary units allow carrying out automatic identification of dynamic models of control objects in industrial environments. In [1, 2] the different aspects of the proposed algorithms are considered and the results computer and bench testing are given. The theorems about relationship of transient characteristics of the elementary links are proffered at first time in this article.

References

1. Alekperli FA, Shabanov MA (2009) Study the relationship dynamic characteristics of link in order to automatically identify their types. Nat Tech Sci 6:515–518
2. Alekperli FA, Shabanov MA (2013) Automatic identification of the structure of the object based on the transient characteristics of the relationship. J Comput Inf Technol 6:11–16
3. Babakov NA (1986) The theory of automatic control, p 424
4. Diligensky AN (2009) Identification of control objects. Tutorial. Samara: CAMP. state, University Press
5. Efimov SV, Zamyatin SV, Gayvoronskiy SA (2010) Structural- parametric identification of the control object on the basis of the characteristics of the transition process. Proceedings of TPU 5:107–112
6. Filimonov AB, Filimonov NB (1993) Structural and parametric identification of dynamic objects. Izv Vuzov Priborostroenie 1:33–38
7. Isidoro P (2011) Electronic resource. http://www.kopras.nm.ru/progs/isidora.html
8. Semenov AD, Artamonov DV, Bryuhachev AV (2003) Identification of control objects. Study posobie.-Penza: Izd Penz. state. University Press
9. Solodovnikov VV, Uskov AS (1960) Statistical analysis of objects regulation. -M .: Mashgiz

Chapter 15
Modeling and Simulation of Logistics Integration of Electronic Commerce Online Shopping Platform

Yi Guo

Abstract With the development of e-commerce, logistics has attracted the attention of big electric business enterprises. Unreasonable picking, slow distribution, and logistics service quality problem have become a bottleneck restricting the development of electronic commerce. This paper put forward design scheme of the integrated storage and distribution system: Electronic business enterprise self-builds or rents distribution centers, then unified manages and dispatches the sellers' goods, so strengthening the control of logistics; the buyer purchases at random, but receives parcel at once, so improving shopping experience. For this scheme, this paper establishes system dynamics model in which electronic business enterprise can transfer cargoes among the sellers, and carries out computer simulation. In the end, according to the simulation results put forward the proposals.

Keywords Logistics · Electronic commerce · System dynamics

15.1 Introduction

With the vigorous development of electronic commerce in our country, in recent years online shopping has become a habit of life and been accepted and loved. In 2013, Chinese online shopping market deals reached 1.85 trillion Yuan which is an increase of 42.0 %. Along with the network shopping's related specification and environment gradually improving, Chinese online shopping market will gradually mature. Electronic commerce is the unity of the business flow, cash flow, information flow and logistics. With the development of information technology, the first three "flow" has been realized by computer and network communication equipment, so in the off-line, the operation of logistics has become the key to efficient and fast e-commerce. But logistics system in our country is in a stage of development, the

Y. Guo (✉)
Management School, Guangxi University of Science and Technology,
Liuzhou 545006, People's Republic of China
e-mail: gypaper@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_15

traditional logistics is still dominant, modernization level is not high, the efficiency is relatively low. When the rapid development of e-commerce encounters inefficient logistics, the contradictions are revealed, for example the capital of e-commerce logistic takes up high, personnel cost is high, distribution is unreasonable, delivery is not timely, quality of service is low. “Double 11” in 2013, main electronic business enterprise represented by Taobao throughout the day produced delivery order about 180 million. Throughout the day more than 60 million orders were dealt by express delivery enterprises. With huge logistics quantity the warehouses could not hold any more goods, and express companies delivered delay, so the complaints from buyers were mostly logistics services.

In order to deal with logistics bottleneck, a few large electronic business enterprises began to self-build logistics platform, such as Jingdong mall, Dangdang, Suning. Taobao and Vipshop also began to invest heavily to self-build logistics system. It shows that electronic business enterprises have entered into the field of logistics to build a four-flow integration platform of e-commerce business flow, cash flow, information flow and logistics [3].

For the boom of electronic business enterprise self-building logistics platform, this paper builds warehousing and distribution integration scheme, and carries out modeling and simulation, which has a certain practical significance. In the model, multiple sellers (suppliers) supply, distribution center of electronic business enterprise stores and sorts, and the distribution center can transfer goods among different sellers; the buyer only receives one parcel. These enhance the complexity and practical significance of the model.

15.2 Logistics System Design for Online Shopping Platform

Electronic business enterprise self-builds or rents distribution center. In the central cities such as Beijing, Shanghai, Guangzhou, Chengdu etc. electronic business enterprise sets up core distribution centers; in the major capital cities establishes regional distribution centers; and uses the surrounding city express companies. Through the unified coordination and administration, logistics warehousing and distribution service network throughout the country is formed.

The seller entrusts the logistics to electronic business enterprise. The seller transports goods to the distribution center nearest him; through the seller’s historical trading data analysis, electronic business enterprise assigns different goods according to different proportions to the corresponding regional distribution centers. When the buyer purchases goods and completes the online payment, the order is generated; the seller through the electric business information system transmits order information to the distribution center; the order is confirmed by inventory management system of distribution center, and delivery state and inventory account are fed back to the seller; picking order is printed out, goods are sorted, allocated and packed, the package is generated, afterwards the appointed express company completes the delivery; after receiving goods, the buyer confirms and pays, the account is cleared by payment platform, the seller's account receives electronic fund.

For many small and medium-sized sellers, the logistics system will realize centralized management, centralized shipping goods, and reduce logistics cost; for the buyer, the logistics system can realize online one-stop shopping, receive only one package, pay only one freight, which improves the buyer's shopping experience; for electronic business enterprise, the logistics system can achieve the integration logistics operation of e-commerce supply chain and the enhancement of enterprise's market competitiveness.

15.3 Logistics System Dynamics Model for Online Shopping Platform

15.3.1 Literature Review of System Dynamics

System dynamics was founded in 1956 by Forrester, a professor at the Massachusetts institute of technology in the United States. This subject refers information feedback theory and system dynamics theory, analyzes the causal relationship of various factors. The system structure is described by using flow chart, and through computer simulation operation, we can get real, objective and accurate simulation results. Application fields of system dynamics involve society, economy, enterprise management, ecological environment, etc. [7]. System dynamics has been widely used in the logistics system, such as the regional logistics system, strategic supplies, supply chain system and so on. System dynamics becomes one of the effective methods of quantitative research on logistics system. System dynamics is mainly used to study the bullwhip effect and inventory management in the field of supply chain logistics. Forrester [2] used system dynamics to build supply chain simulation model including the factory, warehouse, distributor and retailer. Liu [5] used the principle and method of system dynamics to build the simulation model of multi-stage inventory under the supply chain environment. Lin [4] mainly analyzed the bullwhip effect that often occurred in the dairy product three-echelon supply chain networks, and used the corresponding system dynamics model to simulate and analyze. In addition, the system dynamics in the study of complex supermarket distribution system also has a wide range of applications. The system dynamics was used by Liu [6] to determine order and inventory quantity in the supermarket distribution center. Chen [1] and Mu Dong established the flow diagram and system dynamics equations of distribution center distributing to three stores, and connecting with living example simulated, finally drew a distribution center's operating optimization suggestions.

System dynamics is an effective method to study the logistics system, with the advantages of all sidedness, the actual simulation, intuitive image, and the small dependence on historical data. This paper also uses system dynamics method for

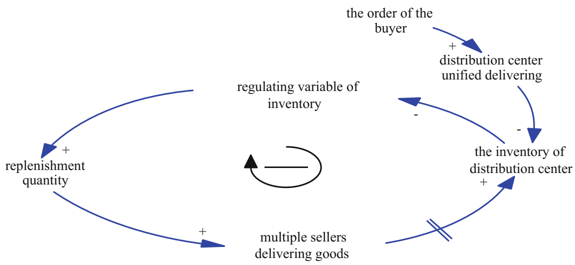


Fig. 15.1 A causal graph of warehousing and distribution system

modeling and simulation. Previous studies are most simple supply chain consisting of single supplier and a distribution center. A bit complexity is system dynamics model that distribution center delivers for three sales shops in supermarket distribution system. This paper is the opposite of previous research models; a distribution center will merge multiple sellers of goods, and then deliver to a buyer. And in order to guarantee rapid and on time delivery, when the inventory is insufficient, distribution center can transfer other sellers' same goods.

15.3.2 Causality Analysis of Logistics System

The various factors of storage and distribution system were analyzed, and in order to clearly show the interaction relationship among the factors, draw the causality diagram, as shown in Fig. 15.1.

From the causal graph, we can see with many sellers' continuous shipment, the goods inventories of each seller increase in distribution center, unified delivery of distribution center will reduce their inventories. To maintain a certain inventory level, regulating variable of inventory becomes smaller. With the reduction of regulating variable, replenishment quantity of distribution center is reduced, which inhibits the sellers' shipments, so form a negative feedback.

15.3.3 System Dynamics Flow Graph Analysis

Dynamic flow graph contain basic variables of system dynamics (box of variables, constants, instrumental variables) and the symbol. Now use Vensim software to set up system flow chart of the electronic commerce enterprise' storage and distribution system as shown in Fig. 15.2.

The model reflects that the buyer can order goods from seller A1 and seller B in online shopping platform at the same time, so order A1 and order B are generated. The sellers' goods are unified managed by distribution center of electronic business enterprise. The distribution center will combine orders, when seller A1's inventory

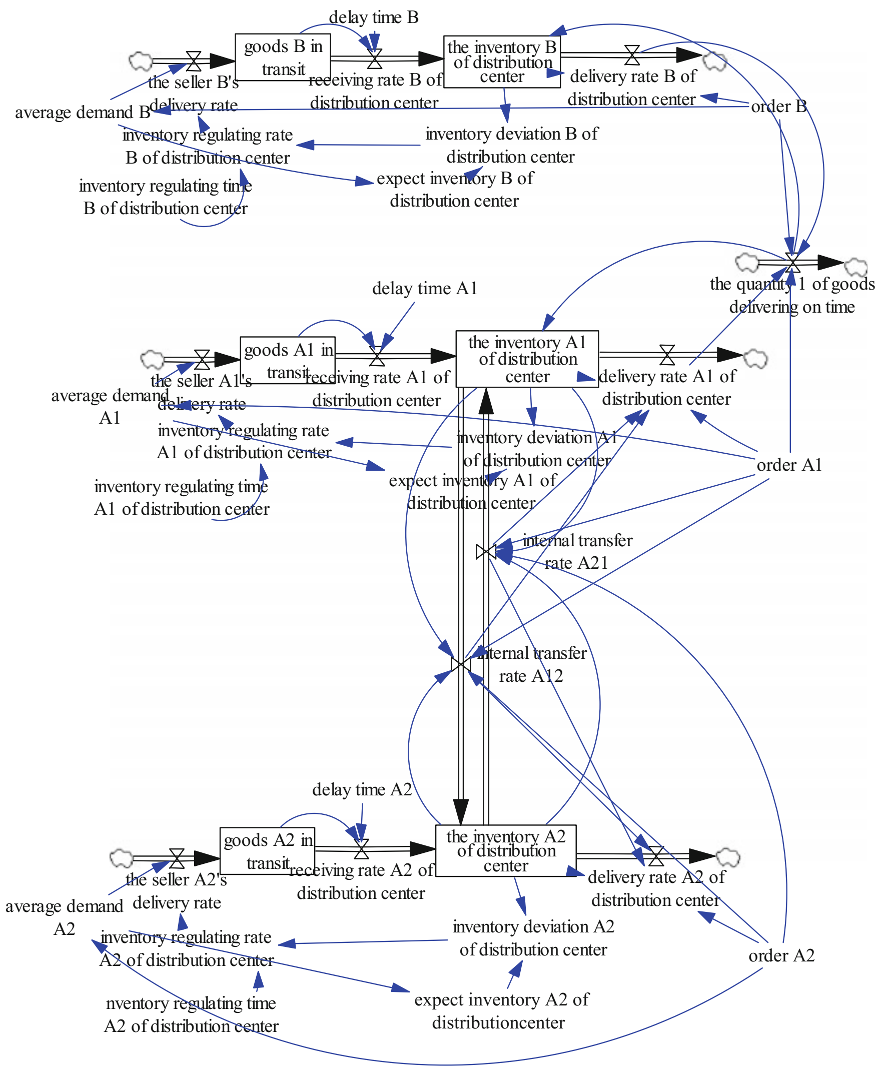


Fig. 15.2 System dynamics flow graph of warehousing and distribution system

is insufficient, distribution center can check the same goods of seller A2 and other sellers; if the seller A2's inventory is residual in addition to satisfy his order of A2, distribution center can transfer the goods of seller A2, then unified pack and together deliver.

15.4 Model Simulation and the Simulation Results Analysis

15.4.1 Simulation of the Integrated Operation of Warehousing and Distribution

After establishing equation system, click on the buttons of Check Model and Units Check in the tool column of Vensim software. It appears that model test passes, then enter the simulation, perform "Run a Simulation", the Simulation curves of each variable are obtained as shown in Figs. 15.3, 15.4, 15.5, 15.6 and 15.7.

As can be seen from the simulation diagram, the inventories A1 of distribution center on the 17–19th day, the 27–30th day appear shortage; the inventories B of distribution center on the 27.5–30th day are out of stock; the inventories A2 of

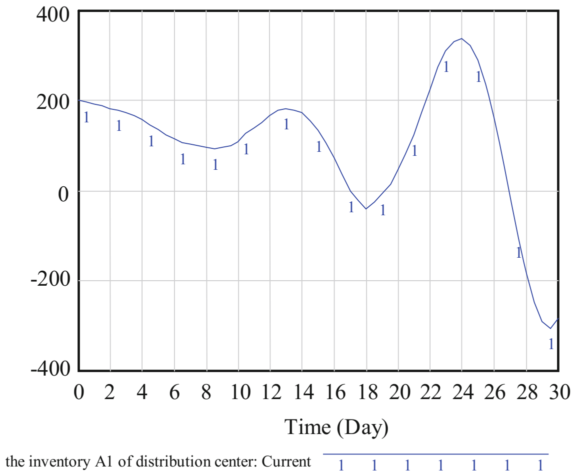


Fig. 15.3 The curve of the inventory A1 of distribution center

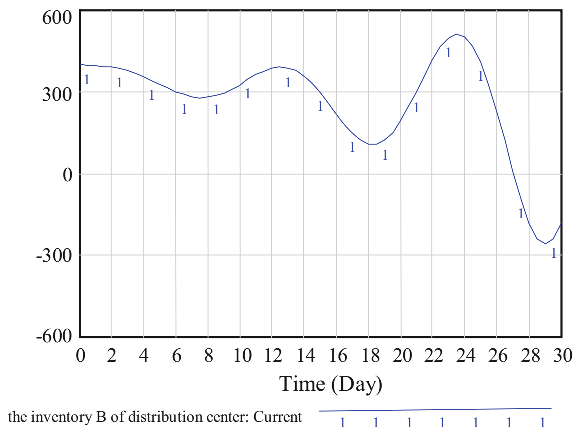


Fig. 15.4 The curve of the inventory B of distribution center

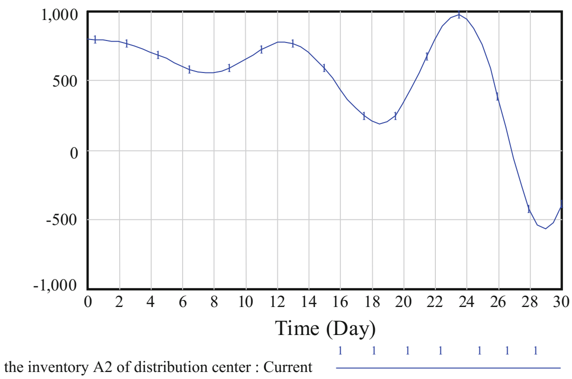


Fig. 15.5 The curve of the inventory A2 of distribution center

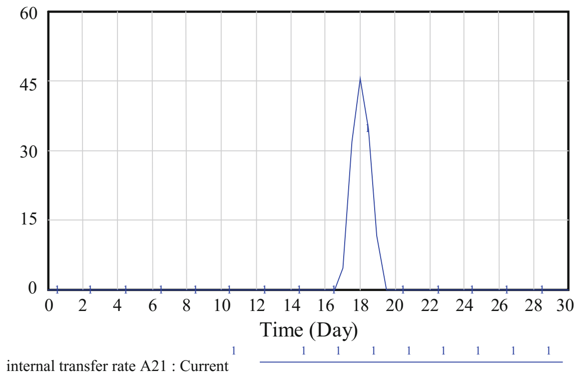


Fig. 15.6 The curve of internal transfer rate A21

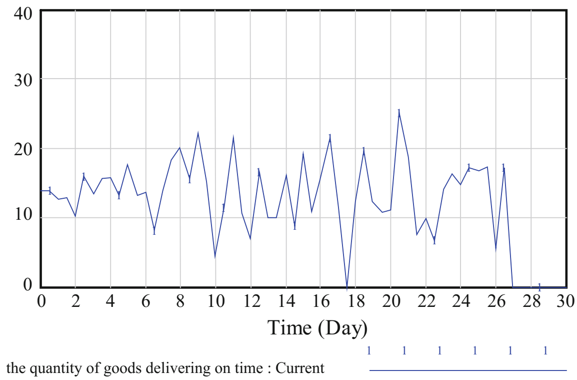


Fig. 15.7 The curve of the quantity of delivering on time of distribution center

distribution center on the 27–30th day are out of stock; internal transfer rates A12 are 0; internal transfer rates A21 on the 17–19th day are greater than zero; the quantities of goods delivering on time on the 27–30th are 0.

These show that on the 17–19th day the seller A1's goods are out of stock, but the seller B's goods can meet the demand of the buyer's order. Distribution center checks the same kind of goods of the seller A2, the seller A2's inventory has some left in addition to satisfy his order A2, so the distribution center on the 17th day transfers 5 units of goods from the seller A2's inventory, on the 18th day transfers 45 units goods, on the 19th day transfers12 units goods, to ensure on the 17–19th day after receiving orders A1 and B from the buyer, distribution center can consolidate orders, and deliver on time. On the 27–30th day, the sellers A1 and A2 seller are both in a state of out of stock, so it means A1 can't transfer goods from A2, internal transfer rates A21 are 0, and the seller B also is in a state of out of stock, so distribution center can't merge the order and deliver on time, thereby the quantities of goods delivering on time on the 27–30th are 0.

15.4.2 *The Influence of the Delivery Delay Time on Distribution Center*

The other variables in the model are unchanged, change the delivery delay time. The original values of delay time of the sellers delivering goods to distribution center are 3 days, now, in turn, it changes for 2 days, 5 days. After inspection, run a simulation, each variable's output of distribution center is as follows, then compare and analyze the outputs.

When delay time is 2 days, red curve 2 is output; for 3 days green curve 3 is output; for 5 days blue curve 1 is output. From Figs. 15.8, 15.9 and 15.10, we can see obviously that with the increase of delay time, each seller's shortage time grows.

As can be seen from Figs. 15.11 and 15.12, with the sellers out of stock, they begin to transfer each other's goods.

As can be seen from Fig. 15.13, with the increase of delay time, punctual delivery faces higher risk.

The simulation results accord with the reality, that shows with the increase of delay time, the sellers' shortage times are also incremental, they need to transfer

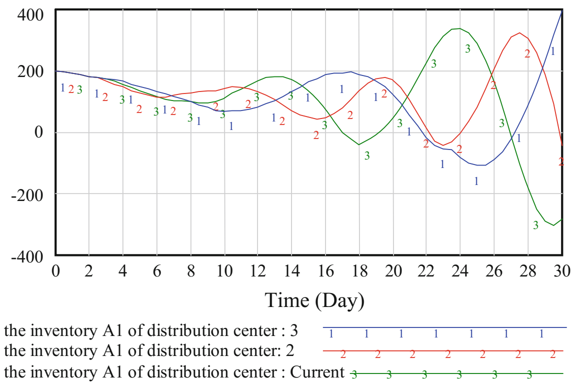


Fig. 15.8 The curve of distribution center's inventory A1 after the delay time changing

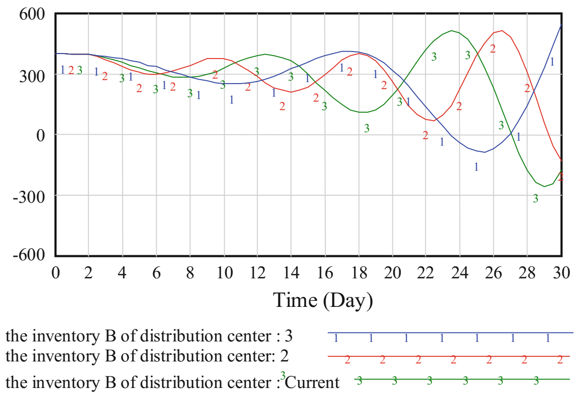


Fig. 15.9 The curve of distribution center's inventory B after the delay time changing

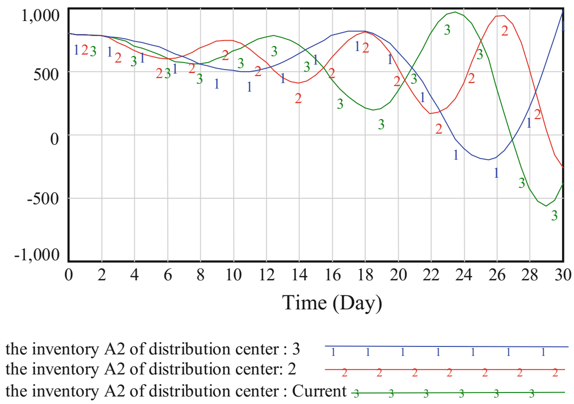


Fig. 15.10 The curve of distribution center's inventory A2 after the delay time changing

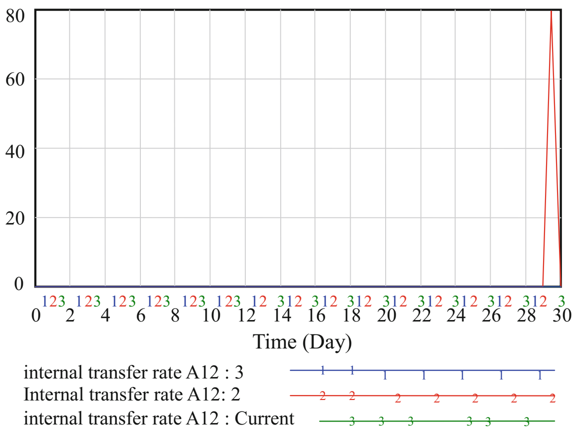


Fig. 15.11 The curve of internal transfer rate A12 after the delay time changing

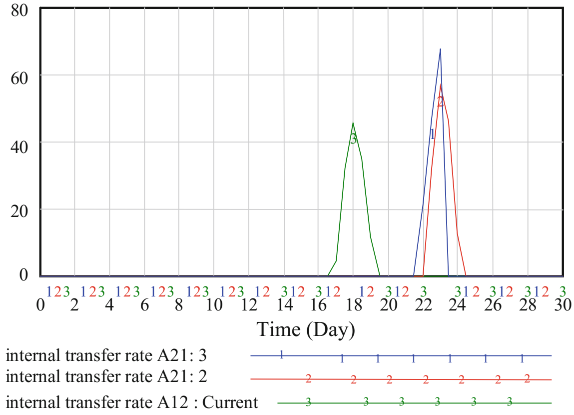


Fig. 15.12 The curve of internal transfer rate A21 after the delay time changing

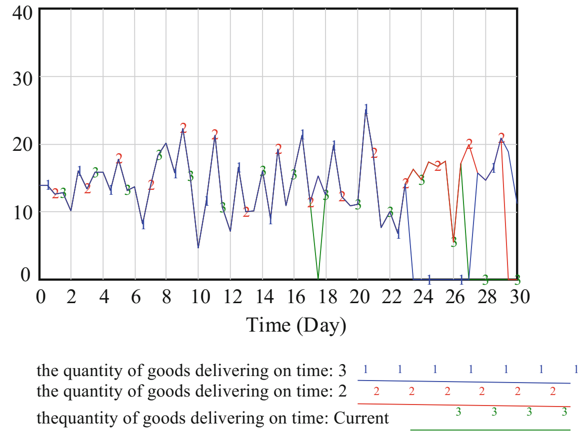


Fig. 15.13 The curve of the quantity of delivering on time after the delay time changing

each other's goods, so the distribution center cannot merge orders, delayed delivery time is increased.

15.4.3 The Influence of Inventory Regulating Time on Distribution Center

The other variables in the model are unchanged, change the inventory regulating time. The original value of inventory regulating time of each seller is 7 days, now in turn, it changes for 5 days, 10 days. After inspection, run a simulation, each variable's output of distribution center is shown from Figs. 15.14, 15.15, 15.16, 15.17, 15.18 and 15.19, then compare and analyze the outputs.

Fig. 15.14 The curve of distribution center's inventory A1 after inventory regulating time changing

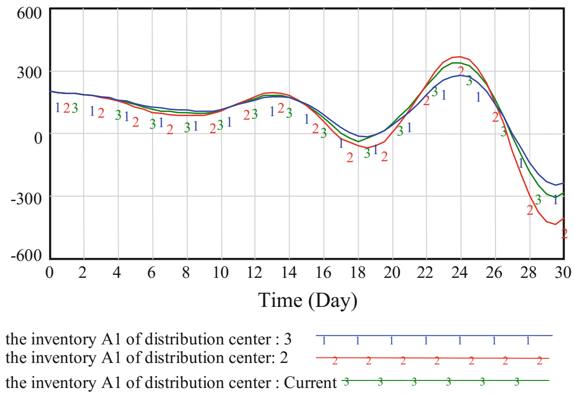


Fig. 15.15 The curve of distribution center's inventory B after inventory regulating time changing

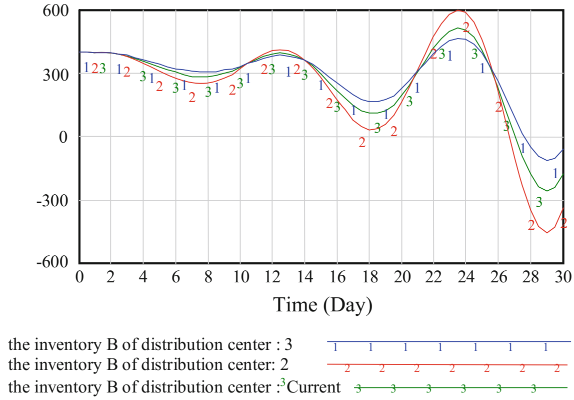
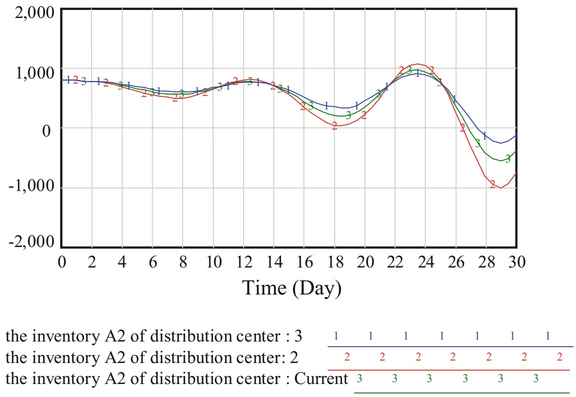


Fig. 15.16 The curve of distribution center's inventory A2 after inventory regulating time changing



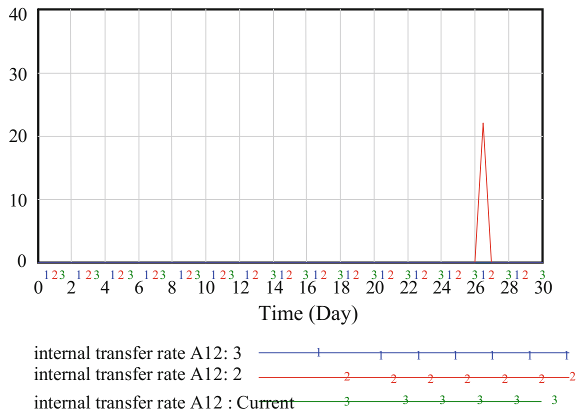


Fig. 15.17 The curve of internal transfer rate A12 after inventory regulating time changing

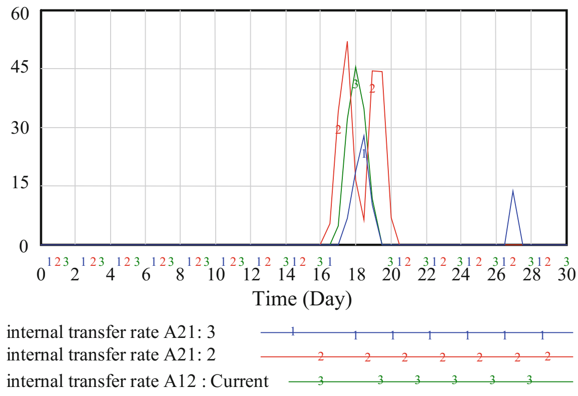


Fig. 15.18 The curve of internal transfer rate A21 after inventory regulating time changing

Fig. 15.19 The curve of the quantity of delivering on time after inventory regulating time changing

When the inventory regulating time is 5 days, red curve 2 is output; for 7 days green curve 3 is output; for 10 days blue curve 1 is output. From Figs. 15.14, 15.15 and 15.16, we can see obviously that with the increase of inventory regulating time, each seller's fluctuation amplitude of inventory curve is small, time and quantity of shortage reduce.

As can be seen from Figs. 15.17 and 15.18, with the sellers out of stock, they begin to transfer goods from each other.

As can be seen from Fig. 15.19, with the increase of inventory regulating time, punctual delivery rate of distribution center is increased.

The simulation results accord with the reality, that shows with the increase of inventory regulating time, the sellers' shortage times are reduced, time and quantity of transferring each other's goods are also decreased, so the distribution center can merge orders, punctual delivery time is increased.

15.5 Conclusion

This paper builds integrated logistics system model of e-commerce purchasing platform. In this system distribution center will centralized manage many small and medium-sized sellers' goods. Centralized distribution guarantee timeliness, and service quality is improved. The buyer can group purchase at will, receive package once, and time and freight cost are saved.

Using system dynamics to simulate for the logistics system, the simulated curve of each variable is output. We analyze the simulation results, and put forward the following suggestions: In the unified management for all sellers' goods in distribution center cases, preventing stockout can ensure that distribution center consolidates orders and delivers on time. To prevent stockout, method is as follows:

(1) strengthen the information communication between sellers and distribution center, realize information sharing, so the seller can understand clearly the inventory in distribution center, and timely replenish to distribution center.
(2) When one seller out of stock, allow distribution center transfers goods from other sellers, which is also one of the ways to effectively prevent stockout.
(3) With the increase of delay time, the sellers' time of stockout is increased, which needs transfer goods from each other, so we should reduce the seller's delay time of delivery.
(4) With the increase of inventory regulating time, the seller's time of stockout is reduced and the time and quantity of transferring goods from each other are also reduced, so we should suitably increase inventory regulating time of distribution center.

Acknowledgments This research is supported by 2015 Guangxi Institution of Higher Education Scientific Research Project under Grant No. KY2015LX182, 2013 Guangxi Philosophy and Social Sciences Planning Project under Grant No. 13BGL009, 2015 Guangxi Philosophy and Social Sciences Planning Project under Grant No. 15BGL006, 2016 Guangxi Middle-aged and Young teachers' Basic Ability Promotion Project.

References

1. Chen W, Mu D (2008) Research on warehousing system at distribution center by system dynamics. J Beijing Jiaotong Univ (Soc Sci Ed) 1:007
2. Forrester JW (1997) Industrial dynamics. J Oper Res Soc 48(10):1037–1041
3. Huang Z (2010) Taobao logistics platform speeding up logistics strategy layout. Computer World
4. Lin B, Jiang M (2015) Simulation of inventory control of dairy product supply chains based on system dynamics. Logist Technol 34:212–215
5. Liu H, Fan A, Gao H (2015) Building running and analysis of the simulation model about multi-stage supply chain inventory based on system dynamics. Logist Sci-Tech 11:93–97
6. Liu S, Zhang X, Zhu D (2011) Study on retail inventory optimization based on system dynamics. Syst Eng 30(5):119–123
7. Zhong Y, Jia X, Qian Y (2010) System dynamics. Science Press, Australia

Chapter 16
Research on Evaluation of Regional Inclusive Innovation Capacity Based on Catastrophe Progression Method

Kunyue Yu, Xin Gu, Changyi Zhao and Yuanyuan Hu

Abstract Based on the analysis of relevant literature, an evaluating indicator system of regional inclusive innovation capacity is built up, and the indicator system is constituted by innovation input, innovation actors and innovation output. According to the indicator system, catastrophe progression method is used in this paper to carry out the empirical analysis of the inclusive innovation capacity on provinces level in China. The result shows that China's regional inclusive innovation capacity demonstrates a "grade-difference" based on differentiation and overall capacity is in the persue layer, and it has a remarkable spatial differentiation of "gradient distribution" which is demonstrated by the facts that capacity in eastern China is more exceptional than that in central and western China. Finally, based on these, this paper gives some advices on development of regional inclusive innovation capacity.

Keywords Regional inclusive innovation capacity · Catastrophe progression method · Evaluation

16.1 Introduction

Since reform and opening-up, the comprehensive innovation from the technology, management to system has promoted the rapid development of China's economy, but the comprehensive innovation has not automatically eliminated poverty, effectively narrowed the income gap, and comprehensively realized social justice and fairness. So central and local government have to rethink ideas and goals of the development

K. Yu · X. Gu · C. Zhao (✉)
School of Business, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 1660035827@qq.com

Y. Hu
Sichuan Power Supply Company, Sate Grid TianFu Area Electric Power Supply Company, Chengdu 610041, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_16

and abandon the simple pursuit of GDP growth in the past, they have to turn to focus on promoting inclusive increase which is more conducive to realize the interests of people of Base of the Pyramid (hereinafter referred to as "BOP"). Inclusive increase commits itself to reduce or even eliminate the phenomenon of unequal opportunity, let every stratum of society fairly share the benefits of development [18]. Finally, inclusive increase makes new demands for regional innovation.

Regional inclusive innovation capacity is the sustaining power of the inclusive increase, and it refers to the ability to use innovation to realize the opportunity fairness in the competition process and fair share of the development results. Regional inclusive innovation capacity focus on broad participation of innovation actors and fairness of innovative income allocation, it could turn traditional regional innovation system which is useful for economic growth to the regional innovation system which is both useful for demands of BOP and economic growth. Because different development history, economic base, resources and environment, different regions have different regional inclusive innovation capacity. So it is necessary to construct and find scientific norm system and evaluation method, so that we can know comprehensively and objectively the level of inclusive innovation capacity of different regions in China, find the distributive characters and developing law of regional inclusive innovation capacity, and promote inclusive innovation and development of every regions in China.

16.2 Literature Review

Most present research of inclusive innovation was qualitative, mostly focused on theory framework, realization path, business model, including: ① Theory framework. Prahald and Allen [8, 9] thought that innovation activities and business behaviour could tackle poverty. Scholl [11] proposed that successful implementation of inclusive business model innovation is based on redefinition of the relation between enterprises and other stakeholders, and he also presented analytical framework of inclusive business model innovation. Wu et al. [16] articulated the differentiation between inclusive innovation mode and traditional innovation mode, and analyzed potential theoretical development within restrict formation and restrict solution in the perspective of theory constructing. Xin et al. [17] elaborated main characteristic of inclusive innovation from different perspectives, and put forward an integrated theoretical analysis framework. ② Realization path. Seelos et al. [13] thought that unconventional and uncertain market environment makes BOP innovation so hard to create value in accordance with the TOP market way. Dacin et al. [4] thought that entrepreneurship is important for BOP innovation based on Social Entrepreneurship Theory. Sonne [15] suggested that financial support and services should be provided to early technology research and development. Ansari et al. [2] proposed that social capital is important for BOP innovation, enterprise should take full advantage of network of resources in the local community. Zhao et al. [19] discussed the effective integration of inclusive innovation and government purchase of public service. Pu et al. [10] discussed the fusion mechanism of inclusive innovation and government purchase of public service. ③ Business model. Hart et al. [7] proposed that lower income groups in developing countries can provide disruptive innovation with natural test sites and ideal development platforms. Hart [6] suggested that enterprises innovation should focus on BOP groups in order to start new growth engine. Simanis et al. [14] suggested that BOP groups which have not never been explored could offer new possibilities for leaping development of enterprise. Schuster et al. [12] thought that success of BOP innovation depends on embedded learning about BOP market. Agnihotri [1] proposed that inclusive business model innovation not only regards low-income earners as customers, but also regards them as suppliers, producers and employees. Zhou et al. [20] put forward a series of suggestions about inclusive development, including disruptive business models. Chen [3] proved that low-cost and convenient payment network about BOP groups is feasible.

There was little research one valuation of inclusive innovation capacity, only including: Zou et al. [21] built up an evaluating indicator system which includes realistic demand, innovation actors, sustaining conditions, innovation environment, innovation output, and composite index method was used to evaluate the inclusive innovation capacity of 31 provinces,autonomous regions and municipalities directly under the central government from 2008 to 2010. Gaoet et al. [5] built up an evaluating indicator system of regional inclusive innovation capacity which includes innovation demand, innovation actors, sustaining conditions, innovation environment, innovation output, and weighting comprehensive evaluation method was used to measure the inclusive innovation performance of 31 regions of China, and provincial panel data from 2008 to 2011 was used to empirically see the relationship between inclusive innovation and foreign direct investment, GDP, industrial structure.

It is obvious that evaluation will be futural important direction of regional inclusive innovation research, but we also can see obvious deficiencies in existing research on evaluation of regional inclusive innovation capacity: at the first place, there have been too many economic and social indicators, but too few innovative ones. At the second place, equal weight or subjective determining weights method which have been used have caused that measurement has been subjective and casual. Last but not least, measurement and computational process is complex. The major contribution of this paper lies in providing an effective evaluation tool for diagnosis of the regional inclusive innovation capability and providing theoretical support for the government to adopt policies to promote inclusive innovation. At the first place, this paper can fully consider characteristics of inclusive innovation and build up an evaluating indicator system which is suitable for evaluating regional inclusive innovation capacity. At the second place, the catastrophe progression method with simple calculation process (which don't need to give a weight to an evaluating indicator) is used to evaluate regional inclusive innovation capacity. Last but not least, the evaluate results are empirically analysed.

16.3 Catastrophe Progression Method and Its Implementing Procedures

Catastrophe progression method is a fuzzy evaluation method, it researches discontinuity characterization near the critical points by analyzing potential function and the classification of critical points, uses normalization formula for comprehensive operation, obtains a parameter as general membership function, and finally accomplishes the goal of ranking analysis of evaluation objects. Compared with general evaluation methods such as AHP, principal component analysis and grey relation analysis, the main advantages of catastrophe progression method are simple calculation process and the absence of weighting. In addition, this method could reduce the subjectivity and maintain the scientificity in evaluation. Implementation steps are as follows:

(1) Building up a multi-objective evaluation index system

All indexes are arranged into tree structure by systematically decomposing overall index from top to bottom. And all indexes are sorted by importance (indexes standing in the front are important ones, indexes standing in the rear are secondary ones), this paper uses entropy method of objective granting weight to determine the importance of indicators.

(2) Determination of catastrophe system model

There are seven catastrophe system models, and they are cusp catastrophe, swallowtail catastrophe, butterfly catastrophe, fold catastrophe, elliptic umbilic catastrophe, hyperbolic umbilic catastrophe and parabolic umbilic catastrophe,the first three types are common basic preliminary catastrophe system models (as shown in Table 16.1).

(3) Normalization formula derivation

The first thing is to compute the first order derivative $g'(x) = 0$ and the second order derivative $g''(x) = 0$ of potential function respectively in order to get bifurcation equation and singular set. In the second place, based on simultaneous equations of the first and second order derivative, bifurcation set equation of catastrophe system could be induced by getting rid of x. Last but not least,normalization formula could be induced by bifurcation equation, in the formula, x_a, x_b, x_c, x_d represent the catastrophe progression of controlled variables a, b, c, d (as shown in Table 16.1).

(4) Comprehensive evaluation

Each of control variable scan be changed into state variables by the normalization formula. In the calculation, when there is not a close relation between a group of

Table 16.1 Catastrophe system model

Type	Potential function	Normalization formula
Cusp catastrophe	$f(x) = x^4 + ax^2 + bx$	$x_a = \sqrt{a}x_b = \sqrt[3]{b}$
Swallowtail catastrophe	$fx = \frac{1}{5}x^5 + \frac{1}{3}ax^3 + \frac{1}{2}bx^2 + cx$	$x_a = \sqrt{a}x_b = \sqrt[3]{b}x_c = \sqrt[4]{c}$
Butterfly catastrophe	$fx = \frac{1}{6}x^6 + \frac{1}{4}ax^4 + \frac{1}{3}bx^3 + \frac{1}{2}cx^2 + dx$	$x_a = \sqrt{a}x_b = \sqrt[3]{b}x_c = \sqrt[4]{c}x_d = \sqrt[5]{d}$

controlled variables (non-complementary type), min x_a, x_b, x_c, x_d is the state variable value. But when there is a close relation between a group of controlled variables (complementary type), the average of x_a, x_b, x_c, x_d is the state variable value. Finally, evaluation objects are ranked on good and bad order according to overall evaluation scores.

16.4 Evaluation of Regional Inclusive Innovation Capacity

16.4.1 Sample Selection and Data Sources

In this study, the research sample consists of 31 provinces, autonomous regions and municipalities directly under the central government except for Hong Kong, Macao and Taiwan,the time for this research is 2012. The data sources of this research are China Statistical Yearbook, China Statistical Yearbook on Science and Technology, China Labor Statistical Yearbook, China Educational Finance Statistical Yearbook, Patent Statistical Yearbook, some data is found by the calculation.

16.4.2 Enactment of Indicator System

(1) Design Thinking about Indicator System

For the evaluation of inclusive innovation or increase, although there are differences in domestic and foreign research, most all researchers measure and analyse inclusive innovation or increase from the prospects of innovation input and innovation output and make a point of effect of innovation actors. Thus this paper intends to empirically research regional inclusive innovation capacity from innovation input, innovation output and innovation actors.

① Innovation input

Innovation input is the allocation of innovation resources in space-time in a region. Factors of production could generally be divided into four categories: land, capital, labor and entrepreneurship in western classical economic theory, but with the development of practice, the role of science and technology as No.1 productive forces has been highlighted, infrastructure also affects the content and efficiency of innovation activities. This paper reduces capital by funds,merges labor and entrepreneurship together into talent, reduces science and technology by knowledge, emphasizes the role of infrastructure which could work for the flow of information and personnel, ignores the role of land, and finally finds out four different innovation input types: funds, talent, knowledge, infrastructure.

② Innovation output

Innovation output is a product of inclusive innovation. Innovation output not only could meet the needs of BOP groups, but also could promote the formation of new economic, social and ecological environment which is good for regional inclusive innovation. Factors of innovation output could generally be divided into four categories: knowledge production, survival conditions, living conditions, social and ecological environment.

To measure of indicators of survival and living conditions,this paper uses demand unsatisfied index DU_{ij} formed by Gao et al. [5] The higher DU_{ij} is, the lower levels of satisfaction of BOP groups is. The high DU_{ij} indicates that the regional inclusive innovation capacity is limited. The formula of the index is:

$$DU_{ij} = \frac{CS_{ij} - RS_{ij}}{RS_{ij}} \times 100. \tag{16.1}$$

In the formula, CS and RS represent consumption of urban and rural households respectively, i represents region, j represents specific needs of products and service.

③ Innovation actors

Innovation actors are the executioners who transform innovation input into innovation output: enterprises, research institutions and universities are main sponsors and undertakers of inclusive innovation activities. BOP groups are valuable consumers, producers and entrepreneurs, they can provide enterprises with information and knowledge which could help enterprises to predict future business models and find potential opportunities for innovation. They also can bring their innovations to market with the help of the enterprises. The higher BOP groups' level of education is, the larger effect of BOP groups is. So raising the educational standards is the key to promoting BOP groups' participation in innovation. Meanwhile, government is also an active participant because it can provide a system guarantee for regional inclusive innovation.

(2) Establishment and Arrangement of Index System

According to catastrophe progression method and considering data availability, this paper respectively selects 11 second grade and 35 third grade indexes from the aspects of innovation input, innovation actors and innovation output to construct the tree structure evaluating indicator system of regional inclusive innovation capacity (as shown in Fig. 16.1).

Calculating weight of every factor based on entropy method, and determining the importance of each indicator according to weight of each indicator (the value in bracket in Fig. 16.1). Finally, ranking the indexes from top to bottom in accordance with the importance of factors affecting orders from big to small (as shown in Fig. 16.1).

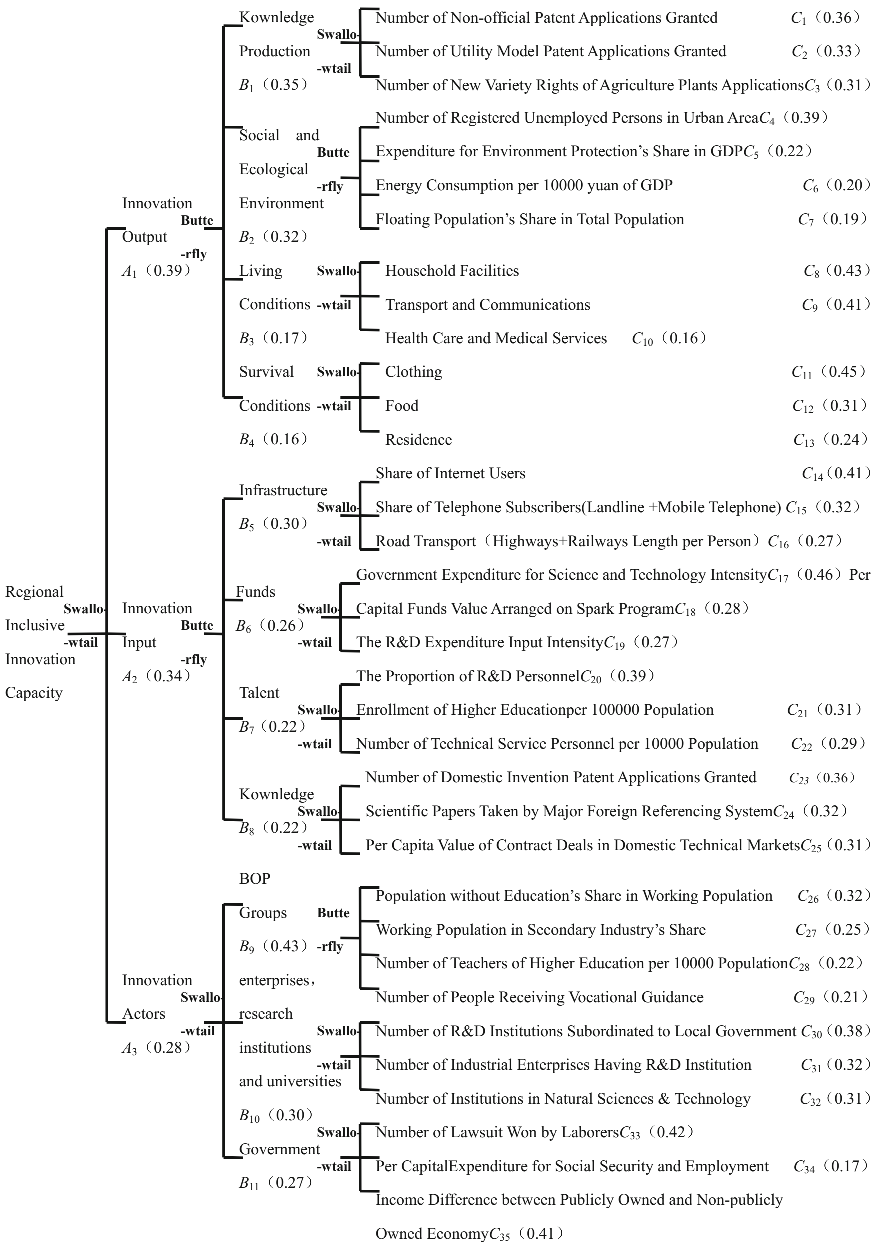


Fig. 16.1 Evaluating indicator system of regional inclusive innovation capacity and catastrophe system type

16.4.3 Determination of Catastrophe System Type

According to the basic principle of catastrophe progression method, determining catastrophe system type of each index layer from the ground up (as shown in Fig. 16.1). According to the relationship between the indexes of different classes, the catastrophe system type of each index lay is complementary.

16.4.4 Standardization of Sample Data

Because the measurement and the utility of different indexes are very different, so different indexes can not be compared directly. It is necessary to standardize indexes firstly. Namely, converting the data from general indexes to positive effect indexes between 0 and 1. Formulas for dealing with the positive and negative indexes by the correction method are:

$$y_i(k) = \frac{u_i(k) - \min\limits_{1 \le i \le m} u_i(k)}{\max\limits_{1 \le i \le m} u_i(k) - \min\limits_{1 \le i \le m} u_i(k)}, \tag{16.2}$$

or

$$y_i(k) = \frac{\max\limits_{1 \le i \le m} u_i(k) - u_i(k)}{\max\limits_{1 \le i \le m} u_i(k) - \min\limits_{1 \le i \le m} u_i(k)}. \tag{16.3}$$

In the formula, $u_i(k)$ represents the value of k index of i sample, $y_i(k)$ represents the standardized value of k index of i sample. $i = 1, 2, \ldots, m$ (m for sample number), $k = 1, 2, \ldots, n$ (n for index number).

16.4.5 Calculation of Catastrophe Progression

According to the indicator system of regional inclusive innovation capacity (as shown in Fig. 16.1), based on statistical data of 31 provinces, autonomous regions and municipalities directly under the central government in 2012, in accordance with approach and steps of catastrophe progression, calculating the value of first-grade indexes and overall objective indicator by the programming software Matlab 7.0 (as shown in Table 16.2).

Table 16.2 Evaluation value and rankings of 31 regions according to regional inclusive innovation capacity

Region	Inclusive innovation capacity		Innovation output		Innovation input		Innovation actors	
	Value	Rankings	Value	Ranking	Value	Ranking	Value	Ranking
Beijing	0.9716	1	0.9259	3	0.9761	1	0.8511	9
Jiangsu	0.971	2	0.9509	1	0.8895	4	0.9077	1
Zhejiang	0.9642	3	0.9427	2	0.8941	3	0.8437	12
Shanghai	0.9591	4	0.8943	8	0.9265	2	0.8382	13
Guangdong	0.9553	5	0.8932	9	0.8666	6	0.876	3
Shandong	0.955	6	0.9193	4	0.8229	10	0.8827	2
Liaoning	0.9501	7	0.8768	15	0.859	7	0.8609	5
Tianjing	0.9499	8	0.8705	17	0.8863	5	0.836	14
Fujian	0.9479	9	0.8952	7	0.8414	9	0.8266	19
Anhui	0.9452	10	0.8974	5	0.7926	15	0.859	6
Hubei	0.9448	11	0.8712	16	0.822	11	0.8642	4
Heilongjiang	0.944	12	0.8892	10	0.7999	13	0.8524	8
Shanxi	0.9437	13	0.8626	20	0.847	8	0.8359	15
Sichuan	0.9435	14	0.8957	6	0.783	18	0.8581	7
Jilin	0.9428	15	0.8829	12	0.8172	12	0.8281	17
Chongqing	0.9382	16	0.8774	14	0.7866	16	0.8315	16
Hebei	0.9352	17	0.8826	13	0.7599	24	0.8264	20
Henan	0.935	18	0.8881	11	0.7352	26	0.85	10
Hunan	0.9346	19	0.8647	19	0.7646	22	0.8476	11
Shanxi	0.9342	20	0.8672	18	0.7783	20	0.8198	22
Neimenggu	0.9306	21	0.8347	25	0.7998	14	0.8147	23
Xinjiang	0.929	22	0.8417	23	0.783	19	0.8068	25
Gansu	0.9276	23	0.8358	24	0.7652	21	0.828	18
Yunnan	0.9221	24	0.8465	22	0.7196	27	0.8145	24
Ningxia	0.9221	25	0.8077	29	0.7854	17	0.7968	28
Jiangxi	0.9194	26	0.856	21	0.6836	29	0.8221	21
Guizhou	0.9147	27	0.827	27	0.7036	28	0.7984	27
Hainan	0.914	28	0.8237	28	0.7491	25	0.7357	30
Guangxi	0.9106	29	0.8309	26	0.6685	30	0.8008	26
Qinghai	0.9103	30	0.778	30	0.7636	23	0.7632	29
Tibet	0.829	31	0.6365	31	0.6137	31	0.4963	31

16.4.6 Evaluation Result Analysis

In order to directly show development and difference of inclusive innovation capacity of regions, according to evaluation result in Table 16.2, this paper divides regional

Table 16.3 Regional inclusive innovation capacity classification

Classifications	Classification standard	Regions
Leading layer	≥0.97	Beijing, Jiangsu
Approximation layer	0.95–0.97	Zhejiang, Shanghai, Guangdong, Shandong, Liaoning
Persue layer	0.93–0.95	Tianjing, Fujian, Anhui, Hubei, Heilongjiang, Shanxi, Sichuan, Jilin, Chongqing, Hebei, Henan, Hunan, Shanxi, Neimenggu
Initial layer	0.91–0.93	Xinjiang, Gansu, Yunnan, Ningxia, Jiangxi, Guizhou, Hainan, Guangxi, Qinghai
Lag layer	≤0.91	Tibet

inclusive innovation capacity into five layers in descending order: leading layer, approximation layer, persue layer, initial layer and lag layer (as shown in Table 16.3).

(1) "Grade-Difference" Based on Differentiation

China's regional inclusive innovation capacity demonstrates a "grade-difference" based on differentiation and overall capacity is in the pursue layer. According to Tables 16.2 and 16.3, through statistics and analysis, average score of regional inclusive innovation capacity of China's 31 regions is 0.9353, demonstrating overall capacity of China's regional inclusive innovation capacity is in the pursue layer. The regional inclusive innovation capacity of China's different regions is obviously different, the score of Tibet is 0.8290 which is the lowest, and the score of Beijing is 0.9716 which is the highest, the highest score is 0.1426 points higher than the lowest score, it is a big gap in calculation of catastrophe progression method. The average score of regional inclusive innovation capacity of five levels are 0.9713, 0.9568, 0.9407, 0.9189 and 0.8290 respectively, the average score of regions in the pursue layer is 0.1423 points higher than that of regions in the lag layer, there are some major disparities in inclusive innovation capacity between different regions.

The development structure of the China's regional inclusive innovation capacity shows "big middle of two small": regions in the approximation layer, pursue layer, initial layer account for 16.13, 45.16, 29.03 % of the total respectively, regions in the three layers account for 90.32 % of the total. But regions in the leading layer and lag layer account for 6.50, 3.18 % of the total respectively, regions in the two layers account only for 9.68 %.

(2) Remarkable Spatial Differentiation of "Gradient Distribution"

In order to facilitate the study, refer to general statistical classification, China is divided into three major parts: eastern, central and western China. Eastern China includes Beijing, Tianjing, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Hainan, Liaoning etc. Central China includes Hubei, Hunan, Henan, Anhui, Jiangxi, Shanxi, Jilin, Heilongjiang etc. Western China includes Guangxi, Sichuan, Chongqing, Yunnan, Guizhou, Neimenggu, Shanxi, Ningxia, Gansu, Qinghai, Tibet, Xinjiang etc.

China's regional inclusive innovation capacity has a remarkable spatial differentiation of "gradient distribution",capacity in eastern China is more exceptional than those in central and western China. As shown in Fig. 9.2, regions in the leading layer and approximation layer are all located in eastern costal China, regions in the lag layer and initial layer are located in central and western inland except for Hainan. According to Tables 16.2 and 16.3, in the light of eastern, central and western China, analysing regions in the different layers respectively, the gap is more clear. Average score of regional inclusive innovation capacity of eastern, central and western China are 0.9521, 0.9375, 0.9184 respectively. Regions in the approximation layer accounts for the highest part of regions in eastern China, the proportion is 45.45 per cent, and regions in pursue and leading layers account for the second and third largest parts, the proportion is 27.27,18.18 % respectively. Regions in the pursue layer accounts for the highest part of regions in central China, the proportion is 87.50 per cent. Regions in the initial layer accounts for the highest part of regions in western China, the proportion is 58.33 per cent. Moreover, the large-small distribution of innovation input, innovation actors, innovation output indicators in spatial dimension is basically in accord with that of regional inclusive innovation capacity, two types of distribution have shown the pattern of strong East-weak West.

The "gradient distribution" feature of regional inclusive innovation capacity is the integrated result of the development differences of history, economy and geographical conditions. From the perspective of history, long-term national differential area development strategy has provided eastern China with a large number of favorable policies and cheap resources, so that the development gap between eastern, central and western China has been further expanded artificially. From the viewpoint of economy, because of limited level economic development, regions in central and western China are difficult to provide enough resources for their own inclusive innovation and increase. From the perspective of geographical conditions, due to bad location, poor transportation condition and bad natural environment, regions in central and western China have inferior position in inclusive innovation and increase.

16.5 Conclusions and Suggestions

Based on the former studies, this paper builds up an evaluating indicator system of regional inclusive innovation capacity which is constituted by innovation input, innovation actors and innovation output, using catastrophe progression method to carry out the empirical analysis of the inclusive innovation capacity on provinces level in China. The results include: China's regional inclusive innovation capacity demonstrates a remarkable spatial differentiation of "grade-difference" and "gradient distribution", this differentiation easily leads to the long-term lock of inclusive innovation capacity gap among regions.

To narrow the capacity gap, interregional geographical constraint and artificial separation must be broken down, obstacles that prevent the free flow of talent, capital and technology must be removed, in order to prompt the innovation resources to move rationally. And the advanced regions should take their innovation advantage, with the aim of promoting knowledge diffusion and coordinative innovation between leading layer, approximation layer, pursue layer, initial layer, or lag layer.

References

1. Agnihotri A (2013) Doing good and doing business at the bottom of the pyramid. Bus Horiz 56(5):591–599
2. Ansari S, Munir K, Gregg T (2012) Impact at the 'bottom of the pyramid': the role of social capital in capability development and community empowerment. J Manage Stud 49(4): 813–842
3. Chen Y (2015) Business models based on inclusive innovation: the case of M-PESA in Kenya. Forum Sci Technol China 1:156–160
4. Dacin PA, Dacin MT, Matear M (2010) Social entrepreneurship: Why we don't need a new theory and how we move forward from here. Acad Manage Perspect 24(3):37–57
5. Gao T, Liu X, Zhou J (2014) The measurement of China's regional inclusive innovation performance: theoretical model and its empirical verification. Stud Sci Sci 32(4):613–621
6. Hart SL (2005) Innovation, creative destruction and sustainability. Res-Technol Manage 48(5):21–27
7. Hart SL, Christensen CM (2002) The great leap: Driving innovation from the base of the pyramid. MIT Sloan Manage Rev 44(1):51
8. Prahalad C, Hammond A (2002) What works: Serving the poor, profitably. World Resources Institute Retrieved October 15:2007
9. Prahalad CK, Hammond A (2002) Serving the world's poor, profitably. Harv Bus Rev 80(9): 48–59
10. Pu W, Zhao W, Li X (2015) The inclusive innovation of government purchase public service in view of multi-dimensional value pursue. Technol Econ 34(1):46–52
11. Scholl J (2013) Inclusive business models as a key driver for social innovation. In: Social Innovation, Springer, Berlin pp 99–109
12. Schuster T, Holtbrügge D (2012) Market entry of multinational companies in markets at the bottom of the pyramid: A learning perspective. Int Bus Rev 21(5):817–830
13. Seelos C, Mair J (2007) Profitable business models and market creation in the context of deep poverty: a strategic view. Acad Manage Perspect 21(4):49–63
14. Simanis E, Hart S, Duke D (2008) The base of the pyramid protocol: Beyond "basic needs" business strategies. Innovations 3(1):57–84
15. Sonne L (2012) Innovative initiatives supporting inclusive innovation in india: Social business incubation and micro venture capital. Technol Forecast Soc Chang 79(4):638–647
16. Wu X, Jiang Y (2012) Where inclusive innovation emerges: Conceptual framework and research agenda. J Syst Manage 21(6):736–747
17. Xin X, Xue F, Tu J (2015) The origin, principal characters and research framework of inclusive innovation theory. Sci Technol Prog Policy 32(4):1–5
18. Zhao W, Sun Y et al (2014) Inclusive innovation: evolution, mechanism and path selection. Sci Technol Prog Policy 31(6):6–10
19. Zhao W, Li X et al (2015) Research on convergence mechanism inclusive innovation and government purchase public service in view of contracting. Sci Technol Prog Policy 32(2): 127–132
20. Zhou Y, Xie J (2012) Research on Indian "gandhian innovation" and inclusive increase of chinese enterprises. Sci Technol Prog Policy 29(3):84–89
21. Zou X, Xu Z, Song Y (2013) Research on measurement and evaluation of regional inclusive innovation capacity. Sci Res Manage 34(S1):343–348

Chapter 17
Barriers in Adopting M-banking System in Universities–A Case Study of Public Universities of Jamshoro, Pakistan

Adnan Asghar Ali and Asif Kamran

Abstract Educational sector is an important sector which plays a significant role in the development of human capital and ultimately in the economic development of the country. Three public universities "are working in the proximity of Jamshoro, Pakistan more than 50 years. Where university administrations are highly committed to provide the quality education simultaneously they are responsible to hardly consider the services that they provide to students, like the fee-paying system in university. The primary objective of this research work is, to utilize the maximum benefit of technology and solve the issues of students towards traditional fee-paying system by adopting the mobile banking system in university. The research methodology is quantitative approach and data collecting tool is closed ended questionnaire. In order to analyze satisfaction level, so run the Chi square, for identification of issues in fee payment measuring frequencies and correlate issues with students' satisfaction so applying partial correlation. In order to analyze the administrative authorities' perceptions towards ICT to innovate traditional system, applying bivariant correlation, finally measuring frequency for barriers in adoption m-payment system.

Keywords M-banking · M-commerce · E-banking · EDI · Innovative fee paying system · Technology adoption · Innovation resistance · M-banking adoption in developing countries

A.A. Ali (✉)
Department of Management Science, Institute of Business and Technology, Karachi 74700, Pakistan
e-mail: asifkamrankhan@gmail.com

A. Kamran
Faculty of Management Science and Social Science,
Institute of Business and Technology, Karachi 74700, Pakistan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_17

17.1 Introduction

The students' population of public sector universities is enough high and by the scale of time it's increasing continuously, in such cases both the university responsibilities and students' strength are directly proportional. As university administration is highly committed to provide the quality education simultaneously it is responsible to hardly consider the services which they provide to the students like the fee-paying system in university. Student satisfaction has become a major challenge for the universities and it has been observed that student satisfaction is the major source of competitive advantage. The developing countries are adopting modern technological methods and techniques to solve the various issues of traditional fee paying system.

These public universities are working in the proximity of Jamshoro, Pakistan from approximately more than 50 years and one of these is the 2nd oldest university of Pakistan. In 21st century where these universities have well information and communication technology infrastructure and are also fully equipped; still these universities are not fully adopting the modern tools of technology towards the solution of traditional fee-paying system. Public universities of Jamshoro, Pakistan can utilize the mobile banking service to facilitate the students for paying their fee without facing any issues like long queue etc. Mobile banking system is not only in favor of students but also, the bank employees as well as university employees can do other works effectively without any disturbance.

17.1.1 Defining M-Banking and Innovation

The use of mobile device, commonly a mobile phone, to make a payment transaction, where funds are shifted from payer to payee, either by a bank or directly, without an agent [16]. Mobile Financial Service refer jointly to a set of applications that allow people to use their mobile phones to control their bank account, store value in an account linked to their handsets, shift funds, or even access credit or insurance goods [5]. At a very general level, an innovation has been defined as an "idea, practice or object that public see as different" [29].

17.2 Literature Review

17.2.1 Mobile Banking Adoption in Developing World

The valuation in technical world especially in the telecommunication sector has made it possible to offer innovative, location sensitive services on everywhere basis to customers on the move [11]. With the help of recent information and communication technology, M-banking as a unique type of banking service carrier that can give efficient and effective financial services for non-bank account holders and rural peoples [13]. Handling money via electronic devices should be accept for the sake of society, economic development and to benefit the mass of the population, including the poor [4]. For comprehensive growth, the benefits of M-banking should reach to the ordinary man at the outmost locations in the country [23]. M-commerce also has huge potential to get better and expand markets, generate jobs and build a middle class [7]. M-banking would be increasingly used from "Building customer relations, reducing cost, achieving new revenue stream" etc. [27].

17.2.2 Barriers to Innovation Adoption

Many organizational and systemic factors that may affect an organizations' decision to accept an innovation. These mediator factors contain Political [14], Organizational [24], Managerial [21], Culture [10], economic and technological characteristic etc. [20]. According to the theory of adoption and diffusion of novel products by a social system has been widely researched by Rogers since 1962, establishing the base for realistic function of novel product introduction there are significant gaps in our knowledge. The most important issue reflects the risks that engage potential barriers to the acceptance of innovation [1]. The greater part of perceive technology as being complex, difficult to learn, and complicated [8]. The innovation is the challenge of examine and reduce organizational resistance in determining whether the people are superior resources for the innovation offer. In addition the adoption of new technology in different countries has met also with different several other barriers as well that is, lack of management support, availability of trained staff, training understanding of technology, lack of organizational coordination and conflicts, skill shortage and lack of expertise [18].

17.2.3 Problem Statement

The Jamshoro's public universities have excellent ICT and infrastructure related facilities yet they are practicing traditional fees payment system resulting in long queues and waste of time. By adopting modern technology based methods the traditional fee paying system issues can resolve and make the students more relax and save time for their studies.

17.2.4 Objectives

The study attempted to answer the following questions:

- To analyze the students satisfaction level towards the present fee paying system and adoption m-payment service;

- To identify the issues related the present fee system;
- To identify the hindrance factors by universities in adopting the m-payment system.

17.2.5 Hypotheses

Hypothesis 1a (H_{1a}): Students are not satisfied with old traditional fee-paying system

Hypothesis 1b (H_{1b}): Students wants to replace traditional fee-paying system by M-banking

Hypothesis 2 (H_2): Traditional fee-payment issues are cause of students' dissatisfaction

Hypothesis 3a (H_{3a}): Security risk and university's culture are barriers in adoption M-banking system

Hypothesis 3b (H_{3b}): Perceived usefulness of ICT can innovate traditional system

Hypothesis 3c (H_{3c}): Competitor pressure can replace traditional system with M-banking

17.3 Methodology

This is a qualitative research work, where the primary data was collected by the close ended questionnaires by using the five points Likert scale. In order to analyze the students satisfaction level towards present fee paying system and barrier in adoption mobile banking system in university will be analyzed by applying the tests (chi-square, partial and bivariant correlation) test with a statistical research instrument SPSS (Statistical Package for the Social Sciences).

17.3.1 Scope and Limitation

The research work is related to the issues and satisfaction level of students' towards traditional fee-paying system and identification of barriers in adoption M-banking system in Jamshoro universities and this work is only for fee-paying system.

17.3.2 Sample

The samples for this study are categorized in two sections: (a) students: The sample size is limited to 300, taking 100 students from each university of Jamshoro, (b) universities administration: The sample size is limited to 21, taking 07 administrative authorities from each university of Jamshoro, i.e. (Admission, Registrar, Examination, Finance, Planning development, HR and IT officers).

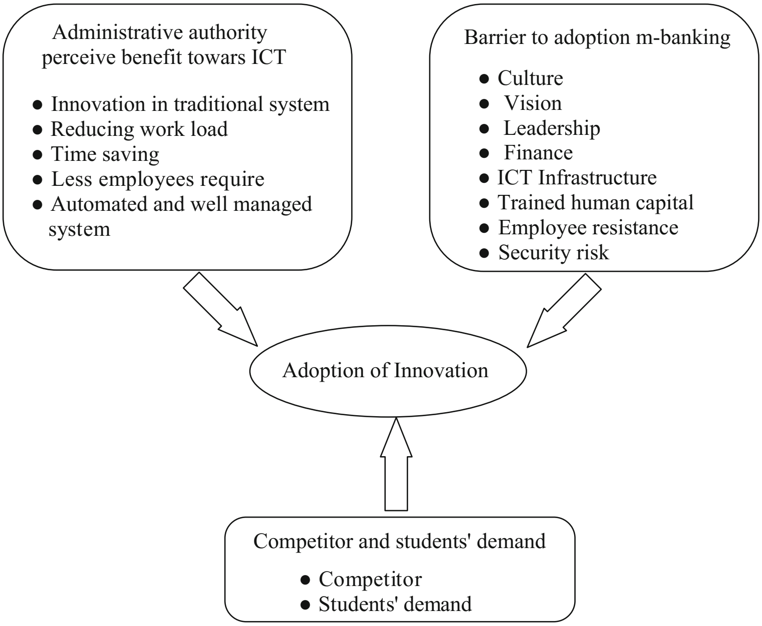


Fig. 17.1 Lacovou's IT innovation adoption model of study

17.3.3 Lacovou's IT Innovation Adoption Model of Study

To explore the hindrance factors to adoption m-payment system, using a proposed model of Lacovou's "adoption IT innovation". Proposed model factor and other identified hindrance factors by the following authors from literature helped in making a new model, to identify the hindrance factors facing by public universities administration to adoption M-banking system. This model is based on three factors: Perceived benefits, organizational readiness and external pressure, each factor is further deeply categorized with respect to the identified barrier's factors from literature, as shown in the Fig. 17.1.

17.4 Presentation of Data

(1) Students' satisfaction towards traditional system

Table 17.1 revealed that, Pearson chi-square value 0.000 is significant and rejecting the null hypothesis H_{1a} and showing that students are not satisfy to keep continue university's traditional fee paying system in modern era of technology.

Table 17.2 pearson chi-square value 0.000 is significant and rejecting the null hypothesis H_{1b} and showing that that students are satisfy to replace this traditional

Table 17.1 Chi-square test for students' satisfaction towards traditional system

	Value	df	Asymp. Sig. (2-sided)	Exact. Sig. (2-sided)	Exact. Sig. (1-sided)
Pearson Chi-square	3.84E + 02	1	0	–	–
Continuity correction	380.807	1	0	–	–
Likelihood ratio	441.677	1	0	–	–
Fisher's exact test	–	–	–	0	0
Linear-by-Linear association	383.36	1	0	–	–
N of valid cases	600	–	–	–	–

Table 17.2 Chi-square test for students' wants to replace traditional fee system

	Value	df	Asymp. Sig. (2-sided)	Exact. Sig. (2-sided)	Exact. Sig. (1-sided)
Pearson Chi-square	4.72E+02	1	0	–	–
Continuity correction	468.167	1	0	–	–
Likelihood ratio	570.542	1	0	–	–
Fisher's exact test	–	–	–	0	0
Linear-by-Linear association	470.92	1	0	–	–
N of valid cases	600	–	–	–	–

system with a new technological based system i.e. M-banking which is handy and relax from all issue of traditional system.

(2) Identified issues in traditional fee system

The issues are facing during the fee submission process are collecting challan forms, HODs initial and departmental stamps, long queue outside the bank, limited timings of bank and limited operational days of bank.

These issues are arranging with respect to the calculated mean values, where the "standing in long queue", "HOD's initial and stamp", "collecting challan forms", "limited working hours" and "limited bank's operational day" with mean value 4.63, 4.39, 4.20, 4.14 and 3.85 respectively showing in Fig. 17.2.

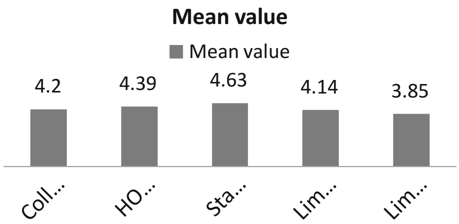


Fig. 17.2 Traditional fee-system issues mean values

Table 17.3 Partial correlation between students' dissatisfaction and group 1

Group 1: Control variables			Departmental stamp	Collecting challan forms from bank
Unsatisfied with overall process of traditional fee paying	Departmental stamp system	Correlation	1.000	0.401
		Significance (2-tailed)	–	0.000
		df	0	297
	Collecting challan forms from bank	Correlation	0.401	1.000
		Significance (2-tailed)	0.000	–
		df	297	0

Table 17.4 Partial correlation between students' dissatisfaction and group 2

Group 2: Control variables			Departmental stamp	Standing in long queue
Unsatisfied with overall process of traditional fee paying system	Departmental stamp	Correlation	1.000	0.22
		Significance (2-tailed)	–	0.00
		df	0	297
	Standing in long queue	Correlation	0.22	1.000
		Significance (2-tailed)	0.000	–
		df	297	0

(3) Partial correlation between issues and students' dissatisfaction

Several issues has been explored in exists university fee payment system. To identify the correlation between explored issues in current fee paying system and dissatisfaction attitude of student, apply the partial correlation. In this test students dissatisfaction is set a control variable and issues are other variables, issues are set as in groups like (group 1, 2, 3 and 4) where finding the correlation between issues and students' dissatisfaction toward current fee payment system. Table 17.3 for group1 (departmental stamp and collection challan forms from bank) 0.401, Table 17.4 for group 2 (departmental stamp and standing in long queue) the value 0.22, Table 17.5

Table 17.5 Partial correlation between students' dissatisfaction and group 3

Group 3: Control variables			Standing in long queue	Collecting challan forms from bank
Unsatisfied with overall process of traditional fee paying system	Standing in long queue	Correlation	1.000	0.295
		Significance (2-tailed)	–	0.00
		df	0	297
	Collecting challan forms from bank	Correlation	0.295	1.000
		Significance (2-tailed)	0.000	–
		df	297	0

Table 17.6 Partial correlation between students' dissatisfaction and group 4

Group 4: Control variables			Limited working hours of bank	Limited operational days of bank
Unsatisfied with overall process of traditional fee paying system	Limited working hours of bank	Correlation	1.000	0.493
		Significance (2-tailed)	–	0.00
		df	0	297
	Limited operational days of bank	Correlation	0.493	1.000
		Significance (2-tailed)	0.000	–
		df	297	0

for group 3 (standing in long queue and collecting challan forms from bank) the value 0.29 and Table 17.6 for group 4 (limited working hours of bank and limited operational days of bank) the 0.49 are showing positive correlation and accepting the H_2 that traditional fee-payment issues are cause of students' dissatisfaction.

(4) Administrative authority perception towards ICT

To analyze the university administrative authority perception towards ICT usefulness to innovate traditional fee paying system by adopting ICT applying the bivariant correlation.

In this test "perceive usefulness and benefits of ICT" is first variable and other variable "Perceived that ICT can make traditional system innovative". The perception of universities administrative authority towards ICT usefulness to innovate current traditional fee payment system is significant as shown in Table 17.7, 0.139 and positive correlation, that accepting the H_{3b} research hypothesis.

The Lacovou's model factors, culture, vision, leadership, finance, ICT infrastructure, trained human capital, employee resistance and security risk are individually

Table 17.7 Bivariant correlation between perceived usefulness of ICT and perceived ICT to innovative traditional system

		Perceived usefulness and benefits of ICT	Perceived that ICT can make traditional system innovative
Perceived usefulness and benefits of ICT	Pearson correlation	1	0.139
	Sig. (2-tailed)	–	0.549
	N	21	21
Perceived that ICT can make traditional system innovative	Pearson correlation	0.139	1
	Sig. (2-tailed)	0.549	–
	N	21	21

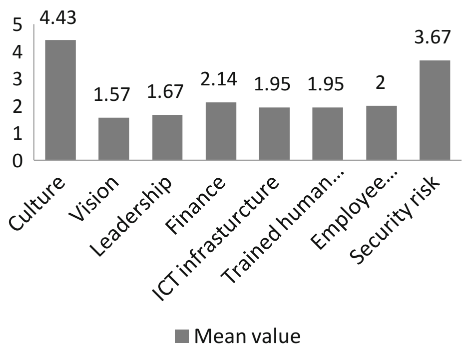


Fig. 17.3 Barriers mean values

testing for the barrier identification in adoption m-payment system in Jamshoro universities.

The identified barriers arranging with respect to the calculated mean values, where two factors “culture 4.43” and “security risk 0.67” are highly rated by university administrative higher authorities as barrier as shown in Fig. 17.3. The two highest mean values of culture and security risk factor are accepting the research H_{3a}.

(5) Competitor and Students’ pressure

The past studies of technology adoption examined in general where found several factors that impacting the adoption decision of ICTs in organizations and these factors classified in two types i.e. internal factors and external factors [15]. The external factors of technology adoption decision of ICT be at three levels, industry, macroeconomic and national policy and these three factors have on effect at the general and competitive environment within where these firm operate [15]. In competitive environments of business the external pressure have a great influence to the adoption of advance ICT technology. Not only in developing countries but several examples of U.S companies that adopted the ICT mainly because of competitive pressure [2, 9]. In another study of developed countries found that some organizations accepted new suppliers, those demonstrate an electronic data interchange capability or demonstrate the ICT adoption [22]. After the competitor pressure, the students also considered as

Table 17.8 Bivariant correlation between perceived competitor pressure and not offering M-banking service

		University perceived competitor pressure towards traditional fee system	University not offering M-banking service because still no any university in Pakistan offering
University perceived competitor pressure towards traditional fee system	Pearson correlation	1	0.354
	Sig. (2-tailed)		0.116
	N	21	21
University not offering M-banking service because still no any university in Pakistan offering	Pearson correlation	354	1
	Sig. (2-tailed)	0.116	
	N	21	21

the internal factor to put pressure, in adoption of M-banking system in their respective universities for fee-payment.

Universities administrative authorities' perception towards competitors, for replacing traditional system with M-banking tested by applying the bivariant correlation. In this test "University perceived Competitor pressure towards traditional fee system" is first variable and other variable "University not offering M-banking service because still no any university in Pakistan offering". To not perceived competitor's pressure to replace traditional fee-paying system in Jamshoro's universities with M-banking system is significant 0.354 showing positive correlation between the perceived competitor pressures as shown in Table 17.8 and no any university in Pakistan offering M-banking service for fee payment, that is accepting the research H_{3c}.

17.5 Conclusion and Recommendation

This research highlights the students' satisfaction level, issues in traditional fee-paying system and hindrance factors to adopt m-payment system that will helpful for the universities higher authorities and for the head of administrative departments some policies adopt M-banking system in university for the fee payment. This research identified un-satisfaction attitude of students' towards current fee payment system, several issues in traditional fee payment system and resistance of culture factor and technological security risk factor in mobile commerce to implement m-payment service in university. Once the universities higher authorities will overcome the culture factor and incorporating the advance encryption key technology system that will keep students information private as the data flows electronically, then traditional fee system will obsolete and new advanced modern technological based "m-payment" will resolve the students' issues and made them satisfy towards the university fee payment system.

(1) Competitor and Students' pressure

- Students use the suggestions and complaint box of university on regular bases, to inform the university management from their issues
- Jamshoro's universities students should demand to adopt m-payment system for fee submission in their respective universities

(2) Recommendations for university management

- Jamshoro's universities management focus to build their culture to adopt the IT innovation
- University's management focus to develop the strategies for employees training and development with reference to advance information and communication technology
- Administrative management of universities establish their link with IT center of respective campus to train the employees with respect to ICT
- Initially to implement m-payment system, if university's management feel technological security risk in mobile commerce than establish strategic alliance with Telenor Pakistan
- University's management have to realized concerned banks, to focus in e-banking and M-banking despite of traditional banking for fee collection

References

1. Coelho D, Drozdenko R, Jensen M (2010) Re-examining the factors that affect consumer acceptance of innovation. In: Proceedings of the annual conference of the American society of business and behavioral sciences 17:362–375
2. Dasgupta S, Agarwal D et al (1999) Determinants of information technology adoption: an extension of existing models to firms in a developing country. J Glob Inf Manag (JGIM) 7(3):30–40
3. Dholakia RR, Kshetri N (2004) Factors impacting the adoption of the internet among smes. Small Bus Econ 23(4):311–322
4. Diniz EH, de Albuquerque JP, Cernev AK (2011) Mobile money and payment: a literature review based on academic and practitioner-oriented publications (2001–2011). In: Proceedings of SIG global development fourth annual workshop. Shanghai, China, pp 1–27
5. Donner J, Tellez CA (2008) Mobile banking and economic development: linking adoption, impact, and use. Asian J Commun 18(4):318–332
6. Fichman RG, Kemerer CF (1993) Toward a theory of the adoption and diffusion of software process innovations. In: Diffusion, transfer and implementation of information technology, pp 23–30
7. Field RL (2011) Development implications of mobile money: united nations commission on international trade law colloquium on electronic commerce
8. Garrett P, Brown CA et al (2006) Identifying barriers to the adoption of new technology in rural hospitals: a case report. Perspect Health Inf Manag 3(9):1–11
9. Ghosh S (1997) Making business sense of the internet. Harv Bus Rev 76(2):126–135

10. Gopalakrishnan S, Damanpour F (1994) Patterns of generation and adoption of innovation in organizations: contingency models of innovation attributes. J Eng Technol Manag 11(2):95–116
11. Hakim Syed Adnan Ibna IM, Ablakimovich AA (2007) On-going activities of mobile banking in financial sector: focused on mobile banking in different continents and its future trends
12. Iacovou CL, Benbasat I, Dexter AS (1995) Electronic data interchange and small organizations: adoption and impact of technology. MIS quarterly pp 465–485
13. Kumbhar VM (2011) Financial inclusion through m-banking services: scope and problems in India. Technical report, University Library of Munich, Germany
14. Lai VS, Guynes JL (1994) A model of ISDN (integrated services digital network) adoption in US corporations. Inf Manag 26(2):75–84
15. Lefebvre E, Lefebvre LA (1996) Information and telecommunication technologies: the impact of their adoption on small and medium-sized enterprises. 303.483 LEF. CIMMYT
16. Mallat N, Rossi M, Tuunainen VK (2004) Mobile banking services. Commun ACM 47(5):42–46
17. Oliveira T, Martins MF (2010) Information technology adoption models at firm level: review of literature. In: European conference on information management and evaluation, Academic Conferences International Limited, p 312
18. Palvia S, Palvia P, Zigli R (1992) The global issues of information technology management, vol 1. IGI Global
19. Rahman A (2012) Leadership role in handling employee's resistance. Master's thesis, Department of Entrepreneurship Faculty of Business and Finance University, Malaysia
20. Rogers EM (1983) Diffusion of innovations. New York
21. Schein EH (1990) Organizational culture, vol 45. American Psychological Association, Washington
22. Schware R, Kimberley P (1995) Information technology and national trade facilitation, vol 317. World Bank, Technical Paper, Washington, D.C., p 19
23. Shukla NS, Bhatt VK (2012) Understanding the adaptation of mobile banking among consumers: an empirical evidence. Res Expo Int Multidiscip Res J 2(2):1630–16350
24. Strassmann PA (1990) The business value of computers: an executive's guide. Information Economics Press, New Canaan
25. Tiwari R, Buse S, Herstatt C (2006) Mobile banking as business strategy: impact of mobile technologies on customer behaviour and its implications for banks, vol 4. IEEE, New York
26. Udo GJ (2001) Privacy and security concerns as major barriers for e-commerce: a survey study. Inf Manag Comput Secur 9(4):165–174
27. Vaidya SR (2011) Emerging trends on functional utilization of mobile banking in developed markets in next 3–4 years. Int Rev Bus Res Pap 7(1):301–312
28. Yousafzai SY, Pallister JG, Foxall GR (2003) A proposed model of e-trust for electronic banking. Technovation 23(11):847–860
29. Zaltman G, Wallendorf M (1979) Consumer behavior, basic findings and management implications. Wiley, New York

Part II
Logistics Engineering

Chapter 18
Some Estimations for the Mathematical Expectation of Renewal-Reward Process with Nonnegative Rewards

Veli Bayramov and Rovshan Aliyev

Abstract In this paper a renewal-reward process with nonnegative rewards is investigated and some results for the renewal function are generalized to the mathematical expectation of the renewal-reward process. Finiteness of the mathematical expectation of the renewal-reward process with nonnegative rewards is proved. Also under some conditions the inequalities for the renewal function are generalized to mathematical expectation of the renewal-reward process with nonnegative rewards.

Keywords Renewal process · Renewal function · Renewal-reward process · Mathematical expectation

18.1 Introduction

Renewal-reward processes occur in various stochastic optimization models, particularly in Markov and semi-Markov decision processes [1, 2, 5].

In Brown and Solomon [4] there were obtained asymptotic expansions for the mathematical expectation and variance of the renewal-reward process. These are the generalizations of the analogical formulas for the renewal processes. Also, in Patch et al. [6] there was obtained an asymptotic expansion for the covariance function of the rewards of the multivariate renewal-reward process.

The results that obtained for the renewal-reward processes as the generalization of the renewal processes make it necessary to generalize other formulas for the renewal processes to the renewal-reward processes.

V. Bayramov (✉)
Department of Operation Research and Probability Theory, Baku State University, Baku, Azerbaijan
e-mail: veli_bayramov@yahoo.com

R. Aliyev
Institute of Control Systems, Azerbaijan National Academy of Sciences, Baku, Azerbaijan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_18

Our aim is to investigate the renewal-reward process with nonnegative rewards and to generalize some inequalities proved for the renewal function to these processes. First, let us introduce some notations and theorems from literatures.

Consider a sequence of independent and identically distributed random variables $\{X_i, i = 1, 2, \ldots\}$ with common distribution function $F(x) = P\{X < x\}$. Define

$$S_n = \sum\nolimits_{(i=1)}^{n} X_i, \quad n = 1, 2, \ldots$$

$$N(t) = \max\{n : S_n \leq t\}, \tag{18.1}$$

$$H(t) = E\{N(t)\}. \tag{18.2}$$

Equation (18.1) is called a renewal process and Eq. (18.2) is called a renewal function.

Define

$$\mu_k = E\{X^k\} = \int_0^\infty x^k dF(x), \quad k \geq 1.$$

The next theorem is about finiteness of the renewal function [7].

Theorem 18.1 $H(t) < \infty$ *for all* $0 \leq t < \infty$.

The following inequalities have been proved for the renewal function (see Borovkov [3]).

Theorem 18.2 *Let* $F(x)$ *be an arbitrary distribution function. Then for all* $t \geq 0$

$$H(t) \leq 1 + \frac{2t}{m_0}, \tag{18.3}$$

where m_0 *is the median of distribution* F.

Theorem 18.3 *If* $\mu_2 = E\{X^2\} < \infty$, *then*

$$H(t) = \frac{t}{\mu_1} - 1 + r(t), \tag{18.4}$$

where $0 < r(t) < 2 + 2/(m_0\mu_1) \int_0^t G(x)dx$, *and* $G(x)$ *is a "double tail" of distribution, which defined as* $\int_x^\infty \bar{F}(z)dz$.

Corollary 18.1 *Assume that conditions of Theorem 18.3 are satisfied. Then*

$$\sup_{t \geq 0} \left| H(t) - \frac{t}{\mu_1} + 1 \right| \leq c < \infty,$$

where $c \leq 2 + \frac{\mu_2}{\mu_1 m_0}$.

18.2 Main Results

Main purpose of this paper is to generalize Theorems 18.1, 18.2, 18.3 and Corollary 18.1 to mathematical expectation of the renewal-reward process with nonnegative rewards. For this, first, let us introduce some notations.

Consider a sequence of independent random vectors $\{(X_i, Y_i), i = 1, 2, \ldots\}$, where $(X_i, Y_i), i \geq 1$, are identically distributed. Assume that $\{X_i, i = 1, 2, \ldots\}$ is a renewal sequence. Consider the process

$$C(t) = \sum_{i=1}^{N(t)} Y_i, t \geq 0. \tag{18.5}$$

The process C is called a renewal-reward process, and is a generalization of a renewal process (Fig. 18.1).

Example 18.1 (Ross [7]) Consider a system that can be in two states: on or off. Initially it is on and it remains on for a time Z_1; it then goes off and remains off for a time Y_1; it then goes on for a time Z_2; then off for a time Y_2; then on, and so forth.

We suppose that the random vectors $(Z_n, Y_n), n \geq 1$, are independent and identically distributes. Hence, both the sequence of random variables $\{Z_n\}$ and the sequence $\{Y_n\}$ are independent and identically distributed; but we allow Z_n and Y_n to be dependent. In other words, each time the process goes on everything starts over again, but when it goes off we allow the length of the off time to depend on the previous on time.

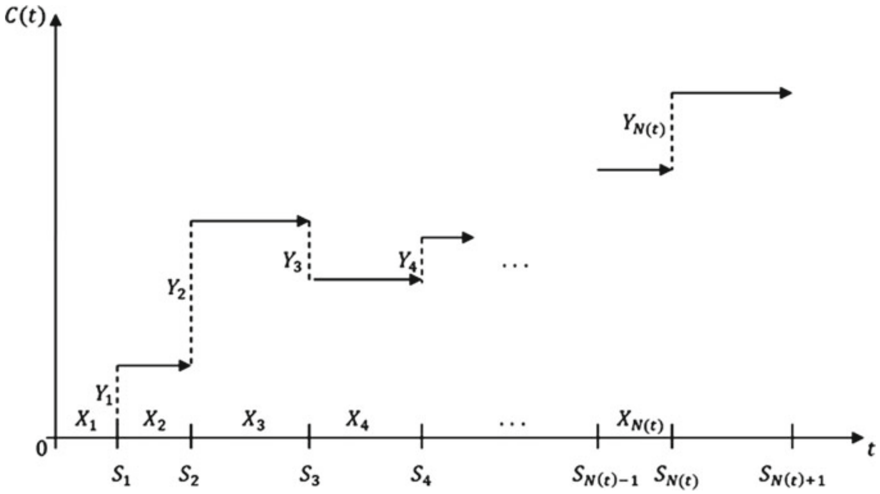


Fig. 18.1 A trajectory of the process $C(t)$

Suppose that we earn at a rate of per unit time when system is on (and thus the reward for a cycle equals the on time of that cycle). Then the total reward earned by t is just the total on time in $[0, t]$, and thus with probability 1 (Ross [7])

$$\frac{\text{amount of on time in [0, t]}}{t} \to \frac{E[Z]}{E[Z]+E[Y]}.$$

Thus when the cycle distribution is non-lattice the limiting probability of the system being on is equal to the long-run probability of time it is on.

Define

$$\lambda_s = E\{Y^s\} = \int_0^\infty E\{Y^s|X=x\}dF(x), \quad s \geq 1,$$

whenever this expectations exist. By existence of an expectation $E\{g(X, Y)\}$ we mean that $E\{|g(X, Y)|\} < \infty$.

Theorem 18.4 *If $Y \geq 0$, $\lambda_1 = E\{Y\} < \infty$, then $D(t) < \infty$ for all $t \geq 0$.*

Proof By the definition

$$D(t) = E\{C(t)\} = E\left\{\sum_{i=1}^{N(t)} Y_i\right\}.$$

As $(N(t)+1)$ is a stopping time for $Y_1, Y_2, \ldots$, then by Wald's equation

$$D(t) = E\left\{\sum_{i=1}^{N(t)+1} Y_i\right\} - E\{Y_{N(t)+1}\} = E\{N(t)+1\}E\{Y\} - E\{Y_{N(t)+1}\}. \quad (18.6)$$

Taking into account $E\{N(t)\} = H(t) < \infty$, $E\{Y\} = \lambda_1 < \infty$ and $E\{Y_{N(t)+1}\} \geq 0$, from Eq. (18.6) can be obtained:

$$0 \leq D(t) = \lambda_1(H(t)+1) - E\{Y_{N(t)+1}\} \leq \lambda_1 H(t) < \infty.$$

This completes the proof of Theorem 18.4.

The next theorems are the generalizations of Theorems 18.2 and 18.3 for the renewal-reward processes with nonnegative rewards.

Theorem 18.5 *If $Y \geq 0$, $\mu_1 = E\{X\} < \infty$ and $\lambda_1 = E\{Y\} < \infty$, then for all $t \geq 0$*

$$D(t) \leq \lambda_1\left(2 + \frac{2t}{m_0}\right), \quad (18.7)$$

where m_0 is the median of distribution F.

Proof Taking into account $E\{N(t)\} = H(t)$, $E\{Y\} = \lambda_1 < \infty$, $E\{Y_{N(t)}\} \geq 0$, and Theorem 18.2 from Eq. (18.6) can be obtained:

$$D(t) = \lambda_1(H(t) + 1) - E\{Y_{N(t)+1}\} \leq \lambda_1(H(t) + 1) \leq \lambda_1 \left(2 + \frac{2t}{m_0}\right).$$

This completes the proof of Theorem 18.5.

Theorem 18.6 *If* $0 \leq Y \leq K$, $\mu_2 = E\{X^2\} < \infty$, *then*

$$D(t) = \frac{\lambda_1}{\mu_1}t - K + A(t), \tag{18.8}$$

where $0 < A(t) < K + 2\lambda_1 + (2\lambda_1)/(m_0\mu_1) \int_0^t G(x)dx$.

Proof Taking into account $E\{N(t)\} = H(t)$, $E\{Y\} = \lambda_1 < \infty$ and Theorem 18.3 from (18.6) can be obtained:

$$\begin{aligned} D(t) &= \lambda_1(H(t) + 1) - E\{Y_(N(t) + 1)\} = \lambda_1(\frac{t}{\mu_1} + r(t)) - E\{Y_(N(t) + 1)\} \\ &= \frac{\lambda_1}{\mu_1}t - K + A(t), \end{aligned}$$

where $A(t) = \lambda_1 r(t) + K - E\{Y_{N(t)+1}\}$. Taking into account $0 \leq Y_{N(t)+1} \leq K$ and the interval for $r(t)$ from Theorem 18.3, can be found that

$$0 < A(t) < K + 2\lambda_1 + \frac{2\lambda_1}{m_0\mu_1} \int_0^t G(x)dx,$$

where $G(x)$ is a "double tail" of distribution F.

This completes the proof of Theorem 18.6.

The next corollary is the generalization of Corollary 18.1.

Corollary 18.2 *Assume that the conditions of Theorem 18.6 are satisfied. Then*

$$\sup_{t\geq 0} \left| D(t) - \frac{\lambda_1 t}{\mu_1} + K \right| \leq c_1 < \infty,$$

where $c_1 \leq \lambda_1 \left(2 + \frac{\mu_2}{\mu_1 m_0}\right) + K$.

Proof By the definition of $D(t)$ and from Corollary 18.1 can be written:

$$\begin{aligned} \sup_{t\geq 0} \left| D(t) - \frac{\lambda_1 t}{\mu_1} + K \right| &= \sup_{t\geq 0} \left| \lambda_1(H(t) + 1) - E\{Y_{N(t)+1}\} - \frac{\lambda_1 t}{\mu_1} + K \right| \\ &\leq \lambda_1 \sup_{t\geq 0} \left| H(t) - \frac{t}{\mu_1} + 1 \right| + K \leq \lambda_1 c + K, \end{aligned}$$

where $c \leq 2 + \frac{\mu_2}{\mu_1 m_0}$.

This completes the proof of Corollary 18.2.

Example 18.2 Assume that X has an exponential distribution with the parameter $\alpha > 0$, so, $F(x) = 1 - e^{-\alpha x}$, $\mu_1 = 1/\alpha$, $\mu_2 = 2/\alpha^2$ and $m_0 = \ln 2/\alpha$. Let us take $Y = e^{-X}$. Then $0 < Y \leq 1$ and

$$\lambda_1 = E\{Y\} = \int_0^\infty e^{-x} dF(x) = \alpha \int_0^\infty e^{-(\alpha+1)x} dx = \frac{\alpha}{\alpha+1} < \infty.$$

The conditions of Theorem 18.5 are satisfied. So, can be written:

$$D(t) \leq \frac{\alpha}{\alpha+1}\left(2 + \frac{2\alpha}{\ln 2} t\right) = \frac{2\alpha^2}{(\alpha+1)\ln 2} t + \frac{2\alpha}{\alpha+1}.$$

Let us find the "double-tail" of distribution F:

$$G(x) = \int_x^\infty \bar{F}(z) dz = \int_x^\infty e^{-\alpha z} dz = \frac{1}{\alpha} e^{-\alpha x},$$
$$\int_0^t G(x) dx = \frac{1}{\alpha} \int_0^t e^{-\alpha x} dx = \frac{1}{\alpha^2}(1 - e^{-\alpha t}).$$

The conditions of Theorem 18.6 are also satisfied. So,

$$D(t) = \frac{\alpha/(\alpha+1)}{1/\alpha} t - 1 + A(t) = \frac{\alpha^2}{\alpha+1} t - 1 + A(t),$$

where $0 < A(t) < \frac{(3\alpha+1)\ln 2 + 2\alpha}{(\alpha+1)\ln 2} - \frac{2\alpha}{(\alpha+1)\ln 2} e^{-\alpha t}$.

Also from Corollary 18.2 can be written:

$$\sup_{t \geq 0} \left| D(t) - \frac{\alpha^2}{\alpha+1} t + 1 \right| \leq c_1,$$

where $c_1 = \dfrac{3\alpha + 1 + 2\alpha \log_2 e}{\alpha + 1}$.

18.3 Conclusion

Renewal-reward processes occur in various stochastic optimization models, particularly in Markov and semi-Markov decision. Thus, generalization results for renewal processes to renewal-reward processes can help investigation of such models.

In this study, finiteness of mathematical expectation of the renewal-reward process with nonnegative rewards is proved. Also, under some conditions, like boundedness of rewards, some inequalities for renewal processes are generalized to renewal-reward processes.

References

1. Aliyev RT, Khaniyev TA (2014) On the moments of a semi-Markovian random walk with Gaussian distribution of summands. Commun Stat Theory Methods 43(1):90–104
2. Aliyev RT, Kucuk Z, Khaniyev TA (2010) Three-term asymptotic expansions for the moments of the random walk with triangular distributed interference of chance. Appl Math Model 34(11):3599–3607
3. Borovkov AA (1976) Stochastic processes in queueing theory, vol 4. Springer Science and Business Media, Heidelberg
4. Brown M, Solomon HA (1975) Second-order approximation for the variance of a renewal reward process. Stoch Process Appl 3(3):301–314
5. Khaniyev T, Kesemen T et al (2008) Asymptotic expansions for the moments of a semi-Markovian random walk with exponential distributed interference of chance. Stat Prob Lett 78(6):785–793
6. Patch B, Nazarathy Y, Taimre T (2015) A correction term for the covariance of renewal-reward processes with multivariate rewards. Stat Prob Lett 102:1–7
7. Ross SM (1996) Stochastic processes, 2nd ed. Wiley, New York

Chapter 19
Vibrational Control of Objects with Distributed Parameters Using Hydrotreating of Motor Fuels as an Example

Ali Gasan Nagiev, Firuza Allahkuli Aliyeva and Hasan Ali Nagiyev

Abstract Using an industrial reactor of hydrotreating of motor fuels as an example dynamical features of models of systems with distributed parameters are studied. The model takes into consideration non-linear effects of absorbing hydrogen by liquid phase, adsorption, desorption and chemical reactions on the surface of a catalyst. On the basis of abundant information material of computational model experiments representing evolution of distribution functions over the longitudinal coordinate of the reactor high sensitivity of such systems to vibrational modes of control is revealed. A mode is detected which represents the formation of "a bean" of wanes, its propagation along the reactor and repetition with a frequency depending on kinetic parameters of physical laws taken into account. An efficiency function allowing to evaluate the results of industrial systems with distributed parameters with respect to impulse and vibrational control strategies is proposed.

Keywords Dynamical systems with distributed parameters · Oscillating control · Hydrodesulfurization process · Optimization

19.1 Introduction

Dynamical systems represented by differential equations in partial derivatives constitute a class of controlled objects which are full of specific features in dynamics. Industrial systems of continuous production are usually employed in stationary conditions with stabilization of some thermal and/or concentration fields following the spatial coordinates. By prescribed integral criteria optimal modes are sought as stationary solutions of differential equations written both in time and space. Among the

---

A.G. Nagiev · F.A. Aliyeva
Sumgayit State University, block 43, Sumqayit, Azerbaijan

H.A. Nagiyev (✉)
The Institute of Mathematics and Mechanics of ANAS, 9 F.Agayev Str., 370141 Baku, Azerbaijan
e-mail: hasan.nagiev@gmail.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_19

first researches in which attention was drawn to the possibility of attaining greater optimality from using artificially of attaining greater optimality from using artificially generated vibrations along both spatial coordinates can be mentioned papers [2, 8, 12]. Then this conception began to be used very widely [6, 7, 9]. Propagating as vibrations control actions which periodically change in time create a certain steady kind of distribution of state parameter along spatial coordinates of an object. In transient modes these distributions, analysis of nature of their evolution are the principal mechanisms of processes.

Responses of objects with distributed parameters to external actions are rather specific. At the same time, one can single out certain classes of industrial processes with characteristic features of vibrational motions. The present research was based on a model of functioning of a catalytic reactor with a stationary layer of a large-grained catalyst. As an object was chosen an industrial plant for hydrocleaning of high-sulfurous motor fuel in a continuous flow of hydrogen-containing gas and raw material. These processes are typical representations of objects with distributed parameters over the longitudinal coordinate of reactors.

A catalytic reaction of combination of hydrogen with sulfur-containing substances comprised in fuels takes place on the surface of a porous catalyst [4, 5, 11]. Chemical processes run parallel with those of absorption of hydrogen molecules in a liquid phase, adsorption, desorption of liquid phase molecules on the surface of a catalyst [1, 3, 10].

There are facts from production practice revealing a strong influence of fluctuations in the velocity of introduction of hydrogen-containing gas on the final results of sulfur cleaning of hydrocarbons being treated. The mentioned fact had prompted an idea about the usefulness of investigating dynamical properties of models of hydrotreating reactors in relation to output data. It was expedient to conduct the model study of non-stationary modes by varying parameters of sinusoidal change in the velocity of introducing gaseous and/or liquid phase into the reactor. The properties of one-dimensional model of chemical fractions in conditions of filtration flow of gaseous and liquid phases in the medium of a large-grained catalyst were studied. The diffusion of both phases was not taken into consideration. The search for gross kinetic parameters was chosen as the main objective. According to the chosen objective, the usefulness of introduction of effective mass-transfer parameters was chiefly in the fact that it opened the way for utilization of empirical data of production technological process.

19.2 A Model of Dynamics of the Chief Variables of Hydrodesulphurization Reactor State

The main simplifying assumption was taken to be the concept of allow ability of the uniting into one group all sulfur-containing substances as the effective kinetic parameters of mass transfer and chemical hydrogenation reactions. Hydrogen sulfide is the product of such reactions. Due to comparatively low isothermal effect of hydro-desulfurization reaction the temperature over the longitudinal coordinate of the reactor is determined only by the temperature at the entry which is mainly influenced by a heating furnace on a raw material line.

The influence of concentration of hydrocracking products and other reactions on the partial pressure of hydrogen in the gaseous phase and on hydrogen solubility in a liquid is negligibly small. The velocity of loss in mass of raw material being treated through hydrocracking with formation of gaseous substances is not considered in the writing of differential equation.

A model with nine variables of the hydrotreating reactor state in the motionless medium of a catalyst was presented in the following form:

$$
\begin{aligned}
&\frac{\partial p_i}{\partial t} - \frac{v_q}{S\sigma_q} \cdot \frac{\partial p_i}{\partial x} - w_{qy}\left(\frac{P}{a_i\left(T\right)} y_i - p_i\right) = 0, i = \{1 - H_2; 2 - H_2 S\},\\
&\frac{\partial y_i}{\partial t} - \frac{v_y}{S\sigma_y \rho_y} \frac{\partial y_i}{\partial x} + \frac{w_{qy}}{P} w_{qy}\left(\frac{P}{a_j\left(T\right)} y_j - p_j\right) + \delta w_{yk}^j\left(b_{yk}^j y_j - z_j\right) = 0,\\
&j = \{1 - H_2; 2 - RS; 3 - H_2 S\},\\
&\frac{dP}{dx} = \frac{1}{S\left(\sigma_y + \sigma_q\right)}\left(\gamma_y v_y + \gamma_q v_q\right),\\
&\frac{\partial z_H}{\partial t} - w_{yk}\left(b_{yk} y_H - z_H\right) + 2 z_H z_{RS} k_0 \exp\left(-E/RT\right) = 0,\\
&\frac{\partial z_{RS}}{\partial t} - w_{yk}\left(b_{yk} y_{RS} - z_{RS}\right) + z_H z_{RS} k_0 \exp\left(-E/RT\right) = 0,\\
&\frac{\partial z_{H_2 S}}{\partial t} - w_{yk}\left(b_{yk} y_{H_2 S} - z_{H_2 S}\right) = 0.
\end{aligned}
\tag{19.1}
$$

The following designations are used in the equations: S, σ_q, σ_y are cross-section area of the reactor as well as fractions of the section occupied by gas bubbles and liquid phase, respectively; $p_H, p_{RS}, p_{H_2 S}$ are partial pressures in gaseous phase of hydrogen, sulfur and hydrogen sulphide, respectively; $y_H, y_S, y_{H_2 S}$ are concentration of the same substances in liquid phase; $Z_H, Z_{RS}, Z_{H_2 S}$ are specific quantity of active centers occupied by molecules of the same substances; v_q, v_y are volume rate of introduction of gaseous and liquid phases; p is pressure in the reactor; p_q, p_y are density of substances in gaseous and liquid phases, respectively; γ_y, γ_q are resistance factor in filtration flow of liquid and gas; w_{qy}^i, ω_{yk}^i are mass transfer coefficients for "gas-liquid" phase and "liquid-solid phase"; $a_i\left(T\right) = K_i^*\left(T\right) + \varepsilon_i^*,\ i = \overline{1,2}$ is linear approximations of temperature dependences of dissolution of hydrogen and hydrogen sulphide in liquid phase, respectively; $\sigma_{yk}^j;\quad j = \overline{1,3}$—coefficients of adsorption on the surface of a catalyst from liquid phase of the corresponding substances; δ is adsorption capacity of a catalyst $[g/g]$; T, R, E, k_0 are temperature, universal gas constant and averaged parameters of hydrodesulfurization reactions-activation energy and pre-exponential factor.

Table 19.1 The parameters of the mathematical model

Group	Name of parameter	Units of measurement	Designations	Values
Evaluations taken from literary sources	Thickness of a catalyst layer	m	L	7.3
	Area of reactor section	m^2	S	16.5
	Specific area taken by a catalyst layer over the reactor cross-section	–	σ_k	0.82
	Parameters of temperature dependence of hydrogen absorption in oil raw material	K^{-1}	k_h^*	0.0097
		–	ε_S	1.63
	Parameters of temperature dependence of hydrogen sulfide	K^{-1}	k_S^*	0.0017
		–	ε_S	1.82
	Effective value of activation energy of formation reaction	$kJmol^{-1}$	E	73
	Effective value of pre-exponential parameter of formation reaction velocity	$\frac{1}{h}$	k_0	0.075
Physical constants taken from reference books	Specific area take by gas bubbles	–	σ_q	0.038
	Specific area taken by liquid phase	–	σ_y	0.062
	Universal gas constant	$JK^{-1}mol^{-}$	R	8.31
Values determined from the solution of identification problem	Equilibrium coefficient at hydrogen adsorption	–	b_{yk}^{H}	1.2
	Equilibrium coefficient at hydrogen-sulfide	–	$b_{yk}^{H_2S}$	1.4
	Equilibrium coefficient at sulfur compounds	–	$b_{yk}^{R}S$	1.41
	Kinetic parameter of absorption	h^{-1}	$w_q y$	2.13
	Kinetic parameter of absorption	h^{-1}	$w_y k$	0.854
	Residence coefficient of filtration liquid flow	$Mpa \cdot h \cdot m$	γ_q	0.26×10^{-2}
	Values of mathematical model parameters	$Mpa \cdot h \cdot m$	γ_y	1.67×10^{-5}

The initial and boundary conditions are prescribed in the form:

At $t = 0$, $p_i(x, 0) \equiv p_{i0}$; $y_i(x, 0) \equiv y_{i0}$; $z_i(x, 0) \equiv z_{i0}$;
at $x = 0$, $p_i(0, t) \equiv p_{i0}(t)$; $y_i(0, t) = y_{i0}(t)$; $z_i(0, t) = z_{i0}(t)$.

The following functions are introduced with the aim of studying responses of the model to periodical control actions on the velocities of gas and liquid admission into the reactor:

$$v_q = v_{q0}\,[1 + u_1 \sin(\omega_1 t)]\,; \quad v_y = v_{y_0}\,[1 + u_2 \sin(\omega_2 t) + \phi]\,, \tag{19.2}$$

where $v_{q0}, v_{y0}, u_1, u_2, \omega_1, \omega_2, \phi$ are varying parameters.

Apparently, the adequacy of the model both in statics and dynamics of transient states is determined by the quality of solving the problem of parametrical identification. The main complication in this was the scarcity of information caused by impossibility of taking samples from the industrial reactor at different points of its longitudinal coordinate. Similar scarcity of information is typical of many production processes being simulated and its most rational solution could be had through creating a lot of testing dynamical actions and identifying by responses from the outlet of an object.

For combination of empirical material of different origin (whether it is taken from literary sources or obtained from our own statistical analysis of an object under study) in a single procedure of identification an expert system of evaluation is employed. According to this strategy, any parameter included in the list of parameters being identified was subjected to preliminary expert analysis for determination of the initial value and determination of the initial value and determination of variation interval. A number of categories of parameters were established such as physical constants, data of branch research institutions, data of science C technical literature and active experiments on an industrial simulation object plus results of statistical analysis carried out by our own effects (see Table 19.1).

The Table below shows values of parameters of the mathematical model after conducting parametrical identification.

19.3 Generation of Controllable Vibrational Motions

The complexity of dynamical relationships between state variables and their nonlinearity lead to the assumptions about the possibility of existence of hidden positive effects in oscillatory motion of this system. As periodic controllable actions it is advisable to apply harmonic actions or an action by a set of impulses having a certain period, type and amplitudes. In this situation of importance is the problem of on action pulse recurrence frequency. We have considered two variants of setting the frequency range: a variant based on a value of characteristic time of pulse passage in relation to the velocity of raw material (in hydrogen-containing gas) introduction and a variant oriented on the scale of a kinetic parameter-mass transfer velocity w_{yk} (Fig. 19.1).

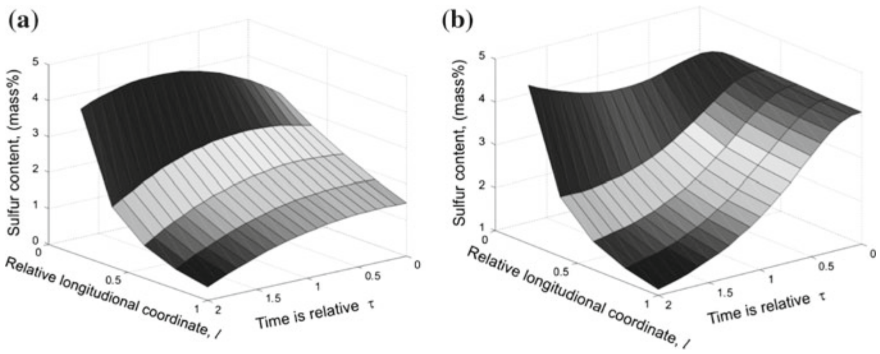


Fig. 19.1 Evolution of distribution function of a sulfur content index of raw material being cleaned $y_{RS}\,(l)$ over the longitudinal coordinate within time interval $t \in [0.2]$ at two velocities of raw material introduction into the reactor: **a** $u = 0, 7$; **b** $u = 1.1$

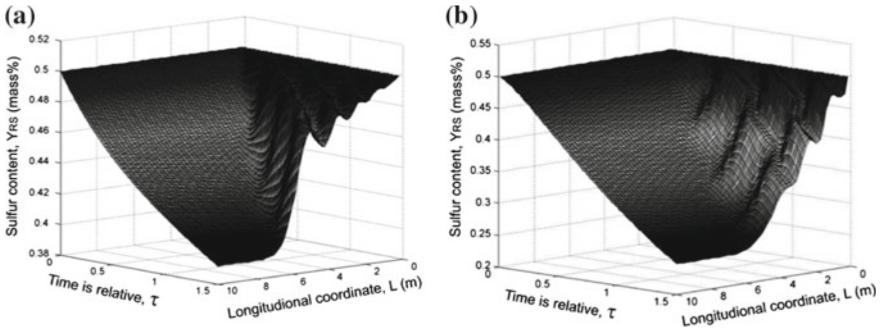


Fig. 19.2 displays non-stationary mode in case of sinusoidal change in the velocity of raw material introduction into the reactor

Figure 19.2 demonstrates dynamics of the transient process of setting the state of equilibrium from a certain initial position $y_{RS}\,(0, 0) = 3$ respectively at a high (variant (a)) and low (variant (b)) value of the velocity of raw material introduction. The transient process is aperiodic at the invariable velocity of raw material introduction which is chosen to be equal to a nominal value $v_y = 170$ m^3/h. From this computational experiment one can determine the characteristic time of the transient process $\bar{\tau} \approx 1.6 - 2.0$.

The same figure presents dynamics of transient states when the initial distribution of concentration is set as uniform ($Y_{RS}(0, l) \equiv 0.5$) while raw material introduction is made according to a harmonically changing law of the following form:

$$u(t) = 0.75(1 + 1.44 \sin 2t), 0 < t < 1.5. \tag{19.3}$$

It is seen from the figure that forming waves which propagate over the longitudinal coordinate increase the amplitude exponentially. By the end of $0 < t < 1.5$ time interval wave process reaching a certain amplitude goes on to infinity. In the course of one minute and a half the wave- front reaches 5–6 m mark of the reactor length. The solution of Eq. (19.1) with the given initial conditions and chosen parameters resembles the known travelling wave mode which is well familiar from theory of dynamical systems.

Highly unexpected became the appearance of wave effects related to internal causes of setting positive feedback among state variables. An effect was discovered when a 20 % increase in kinetic adsorption parameter w_{qy} had brought about auto-generation of waves when all other parameters of the system were invariable. This effect is shown in Fig. 19.3. In spite of the constancy of the velocity of raw material introduction at $u(t) \equiv 170$ m^3/h (nominal value) and uniform initial distribution of sulfur compound concentration over the longitudinal coordinate of the reactor after 0.5 min from the start of the experiment an outburst of a travelling wave group is observed. The discovered effect resembles solutions of a number of models of highly exothermic reactions in displacement reactors [4, 5] and can serve as stimulus for complementing this model with the possibility of orientation on reaction systems with non-exothermic modes.

Figure 19.4 shows the passage of increase pulse of concentration of sulfur compound in the incoming stream. The aim of this model experiment was the study of the impact of kinetic parameter $w_q y$ $w_y k$ (absorption and adsorption) ratio, on the effective velocity of raw material introduction. At high velocities of raw material introduction, i.e. at, $u \leq u^{\text{nom}}$, $\chi = \frac{w_{qy}}{w_{qy}^{\text{nom}}} : \frac{w_{yk}}{w_{yk}^{\text{nom}}} >> 1$ the smoothening of the incoming pulse is detected. The pulse does not reach the reactor exit (the upper indices denote nominal values). A graph presented in Fig. 19.4 corresponds to values of parameters when $u = 1.18u^{\text{nom}}$; $\chi = 0.85$. The explanation of this effect does not constitute any difficulty. Despite the fact that a diffusion constituent of mass transfer velocity is not envisaged in the model (19.1), substance propagation takes place not only by convection but also at the expense of mass transfer between "gas-liquid" phases as the velocity of flow these phases is considerably different.

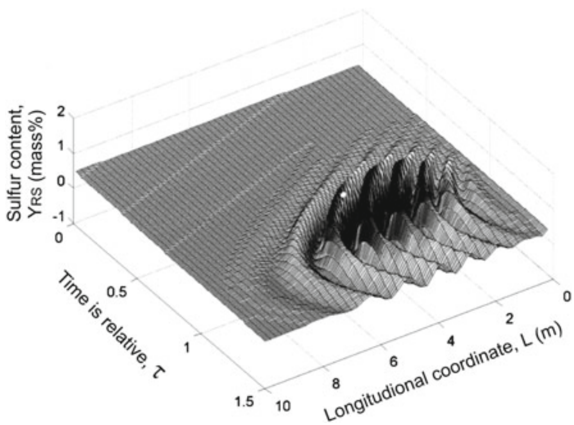


Fig. 19.3 Formation of travelling wave "beam" under the influence of stationary external actions

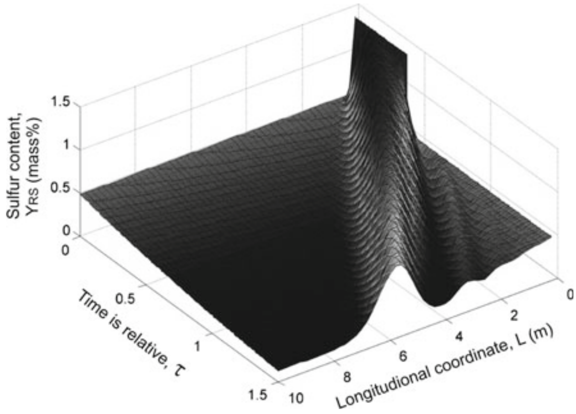


Fig. 19.4 The passage of increase pulse of sulfur compound concentration in the incoming stream at high velocity of raw material introduction and low value of parameter $w_q y$

19.3.1 *Optimization of Mode in the Space of Parameters of Harmonic Action on the Velocity of Raw Material Introduction*

An optimization criterion of non-stationary states of a hydrotreating reactor as well as that of optimization of stationary modes is residual sulfur content of treated raw material, i.e. a quantity:

$$I(\tilde{u}) = \int_0^T y_{RS}(\xi, L)d\xi, T > \tau, \tag{19.4}$$

where T is a certain period of observation; $y_{RS}(\xi, L)$ is a function determined from the solution of system of differential Eq. (19.1); $\tilde{u}$ is vector of function (19.2) parameters.

For determining the optimum mode in model experimentation one can vary a number of parameters of function (19.2). We have studied the influence of parameters v_{y0}, u_2, ω_2 and left parameters $v_{q0}, u_1 = 0$ unchanged.

For each variation of vector $\tilde{u} = \{v_{y0}, u_2, \omega_2\}$; $\tilde{u} \in U$, where U is a domain of varying of components of this vector values of integral (19.4) were computed. Figure 19.5 shows approximations of function (19.4) in a two-dimensional area, i.. $\tilde{u}^{(2)} = (v_{y0\,\min}, v_{y0\,\max}) \times (\omega_{2\,\min}, \omega_{2\,\max})$ at two values of vibration amplitude, $u_2 = 0.2$ (graph (a)) and $u_2 = 0.35$ (graph (b)).

An approximation of these dependences by functions of two parameters at the presented values of parameters was made:

$$y_{RS} = 1.08 - 0.24v_{y0} - 1.03\omega + 0.46\omega^2; \quad u_2 = 0.2,$$
$$y_{RS} = 1.17 - 0.29v_{y0} - 1.1\omega + 0.38\omega^2; \quad u_2 = 0.35$$

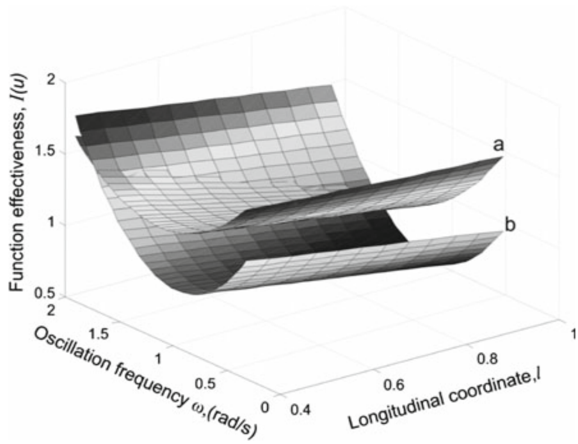


Fig. 19.5 Approximations of effectivity function in a two C dimensional area of vibration control parameters $\tilde{u}^{(2)} = (v_{y0\,\min}, v_{y0\,\max}) \times (\omega_{2\,\min}, \omega_{2\,\max})$ at: **a** $u_2 = 0.2$; **b** $u_2 = 0.35$

The presented graph demonstrates sensitivity of effectivity index of sulfur cleaning process to parameters of change in the velocity of raw material introduction into the reactor. The variants of the computational experiment. (a) and (b) with different degree of visuality show the presence of minimum by frequency coordinate which is a bit displaced for different graphs. This displacement is more pronounced on the portion corresponding to lesser values of constant component of volume rate v_{q0}.

19.4 Conclusion

In conclusion we will note that the conducted computational experiments on the model of hydrogenation reactor in the stationary layer of a grained catalyst have revealed a significant effect showing that the result of the process can be markedly different because of divergences in velocities of mass transfer, by absorption and adsorption. In the said model we have considered only the said physical phenomena of mass transfer, and have taken into account velocities of chemical reactions without consideration for possible effects of longitudinal diffusion believing them to be practically insignificant. We have not taken into account thermal effects of exothermic reactions either. At the same time an important conclusion was made relating to mass transfer of the considered processes which characterizes not only processes of hydrocarbon sulfur cleaning but also any chemical reactions carried out in the stationary layer of a catalyst.

References

1. Afanasyeva Y, Kravtsov N, Ivanchina E (2012) The development of a kinetic model of the process of diesel hydrotreater. Bull Tomsk Polytech Univ 321(3):
2. Butkovskiy A, Poltava L (1965) Optimal control of distributed oscillatory system. Avtomatika I Telemekhanika 26(11):1900–1914
3. Gatica JE, Puszynski J, Hlavacek V (1987) Reaction front propagation in nonadiabatic exothermic reaction flow systems. Aiche J 33(5):819C833
4. Harish K, Pistikopoulos EN (2012a) Optimization and control of pressure swing adsorption processes under uncertainty. Aiche J 59(1):120–131
5. Harish K, Pistikopoulos EN (2012b) Optimization and control of pressure swing adsorption processes under uncertainty. Aiche J 59(1):120–131
6. Harvey AP, Mackley MR, Stonestreet P (2001) Operation and optimization of an oscillatory flow continuous reactor. Ind Eng Chem Res 40(23):5371–5377
7. Martin B, Moshe S (1994) Excitable waves and spatiotemporal patterns in a fixed-bed reactor. Aiche J 40(1):120–130
8. Matros YS (1985) Unsteady processes in catalytic reactors. Elsevier Science Publishing Co Inc, New York
9. Reis N, Pereira RN et al (2008) Enhanced gas-liquid mass transfer of an oscillatory constricted-tubular reactor. Ind Eng Chem Res 47(19):7190–7201
10. Varma A, Giacomo C, Massimo M (2004) Self-propagating solid-solid noncatalytic reactions in finite pellets. Aiche J 36(7):1032–1038
11. Sukhanov VP (1979) Catalytic processes in oil refining. Kchimiya, Moscow
12. Wilson B, Sherrington DC, Ni X (2005) Butylation of phenylacetonitrile in an oscillatory baffled reactor. Ind Eng Chem Res 44(23):8663–8670

Chapter 20
The Impacts of Female Executives on Firm Performances: Based on Principle Component Analysis (PCA) and Data Envelopment Analysis (DEA)

Hanlei Wu and Ying Li

Abstract In the era of information economy with rapid advancement among various industries and increasingly fierce competition among enterprises, managers are seeking for improvement in all aspects of business operation in order to further enhance firm efficiency and effectiveness. On a global scale, it is obvious that female employees participate in each level of enterprise management. In this paper, we briefly surveying literatures on female executives and Chinese SMEs on creative industries, the paper questions whether gender diversity in boardroom can promote firm performance. In order to answer the questions, we conduct a PCA-DEA model to explore the link between them. Furthermore, we establish female executive evaluation index system, then apply data envelopment analysis based on principal components regression, and proposed case studies as followed, then use DEA model to research the impacts of female executives on firm performances. Eventually, the paper draws conclusions that female executives can contribute to the firm performances, and provides some practical suggestions. Based on PCA and DEA methods on the research of women on boardroom in creative industry in China could make a good contribution on the area of female participating on management and researches on creative industries in theory and in practice.

Keywords Female executives · Firm performance · PCA · DEA

H. Wu
Department of Management Science and Engineering, Beihang University, Beijing 100191, People's Republic of China

Y. Li (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: liyinggs@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_20

20.1 Introduction

In the era of information economy with rapid advancement among various industries and increasingly fierce competition among enterprises, managers are seeking for improvement in all aspects of business operation in order to further enhance firm efficiency and effectiveness. On a global scale, it is obvious that female employees participate in each level of enterprise management. An increasingly large number of female executives play a more significant role in enterprise management and decision making. Their impact on corporate behavior has arisen high attention from all walks of life. Increasingly in-depth studies on the diversity of enterprise management, operation management, and firm performance have been conducted.

The board influences and controls the operation and development of the enterprise principally through guiding and controlling managers, providing information consultation, supervising the enterprise implementing the corresponding laws and regulations, developing external social relationships, hiring CEOs, and so forth. A host of scholars suggest that female executives or directors may have corresponding impacts on the working style and the process of management, as well as on firm performance. The reason for increasing the proportion of women in senior management is that the gender diversity in boardroom plays a vital role in enterprise value creation. Although there are many researches show the relationship between gender diversity of the managers and firm financial performance [3, 11, 13, 16], there are some researches shows that the positive relation between them have not been reached [8]. Ahern and Dittmar et al. in their researches [1, 2, 7] argued that female executives and firm performance are negatively related to each other. Haslam et al. in their studies [6, 15] claimed that there is no correlation between them.

The researches proposed a positive relationship of women on the board room and firm performance shows positive impact of female executives' presence, participation, and leadership on the enterprise operation. Based on the research data of fortune 500 companies, Krishnan and Parson suggested that compared to the enterprises with a lower percentage of female executives, those with more female executives have a higher earning quality [9]. The research conducted by Mahadeo Lindstaedt et al. also acknowledge female executives' positive impact on firm performance [3, 11, 13, 16]. Welbourne et al. identified a positive correlation between them by analyzing indexes such as Tobin's, stock price, return-on-investment rate, etc., respectively [5, 10, 16, 17]. In addition, from the perspectives of female executives' different positions in an enterprise, their education, family background, and so forth, Dezso, Smith et al. further confirm female executives' positive impact on firm performance by analyzing the influence of female executives' diverse characteristics on enterprise management. Through an empirical study, Carter [14] found that gender and racial diversity had certain positive effect on firm financial performance. Furthermore, through empirical investigation into small and medium-sized enterprises in Spain, Juan [4] recognized the positive effects of the percentage of female executives on firm financial performance.

Since 1949, women in China have obtained equal rights to work and treatment. Nonetheless, along with economic development and social transformation, an increasingly large number of women's career developments are affected due to family factors, and the number and proportion of women in the enterprise senior management are neither large nor high. This article examines the percentage and characteristics of female executives in listed companies from the Chinese cultural creative industry and their impacts on firm financial performance, seeking to find out whether gender diversity in boardroom of this industry can promote enterprise financial benefit growth? What impacts will the characteristics of female executives have on firm performance? How can an enterprise cope with this and what measures should be taken?

With the advent of the era of creativity, innovation and creativity are becoming crucial points in new economic growth and employment increase, and cultural creative industry become a key industry for China's economic development. Cultural creative industry plays an essential role in economic growth and development of Great Britain, the Netherlands, and other European countries, assisting them to withstand the test of the financial crisis through promoting industrial innovation and transformation, as well as stimulating consumption. By accelerating the integration of the primary, secondary, and tertiary sectors, cultural creative industry itself is growing stronger, becoming a new source of economic growth and a major force of resisting crisis, maintaining stability and promoting development of each country or region. In the post-economic crisis era, The United States also notice the benefits to employment growth produced by the development of creative economy and industry. In 2009 Cultural Industry Revitalization Planning was released in China, and cultural creative industry was taken to a strategic emerging industry level. Women's participation in enterprise management and decision-making in this very industry has practical significance.

In conclusion, based on the above research, in order to further explore the relationship between gender diversity and firm performance in enterprise management, the paper, taking the listed companies from Chinese cultural and creative industry as samples, investigates the impact of the proportion and characteristics of the female executives on firm financial performance in this industry. It comprehensively analyzes various characteristics factors of female executives and indicators of firm financial performance by using the PCA and DEA methods, seeking to verify the impact of gender diversity of board directors on firm financial performance.

20.2 Sample Selection and Variable Definition

20.2.1 Sample Selection and Data Source

The listed companies from cultural creative industry in Shanghai and Shenzhen in 2013 were utilized as the original samples. Twenty-seven samples are obtained by removing enterprises with incomplete important information in the screening process. Then, six enterprises without female executives and four ST and PT companies are rejected from these twenty-seven samples. Ultimately, seventeen cultural industry enterprises samples are obtained.

The sample data are principally from the annual reports, the announcements of important issues, and information disclosure on the official websites of listed companies.

20.2.2 Definition and Description of Research Variables

In this study, the research variables are divided into two categories: the attribute variables of female executives Table 20.1 and the index variables of firm performance evaluation Table 20.2. Based on previous researches, this paper, in variable setting, comprehensively analyzes the proportion and diverse traits of female executives (including their age, duration of director service, professional background, education, management experience, family background, whether serving as a CEO or chairman, and so forth) from the perspectives of female executives' personal qualifications and ability, human and social capital, etc. In terms of enterprise performance, the financial indicators such as an enterprise's asset scale, net margin, return on asset, asset-liability ratio, earnings per share, operating cash flow per share, total assets

Table 20.1 Attribute variables of female executives

Indices	Variable name	Variable meaning
FTMrate	Percentage of female executives	The proportion of women directors among the board of directors
FTMage	Average age of female executives	Average age of female executives
FTMceo	Occupational state of female executive	Whether female executives serve as CEO/chairman: if so, it is denoted by 1; otherwise, 0
FTMtime	Duration of female director service	Duration of female director service
FTMmajor	Professional background of female executives	Pre-employment majors of female executives
FTMPT	Part-time state of female executives	Whether female executives serve as part-timers in other companies: if so, it is denoted by 1; otherwise, 0
FTMedu	Education of female executives	Education of female executives
FTMexper	Management experience of female executives	Whether female executives served as CEO/chairman: if so, it is denoted by 1; otherwise, 0
FTMfamily	Family background of female executives	Whether female executives are supported by a family business

Table 20.2 Index variables of enterprise performance

Indices	Variable name	Variable meaning
COMnet	Net margin rate	Net profit/Major operating revenue
COMROA	Return on asset	Net profit/Average total assets
COMdet	Asset-liability ratio	Debt asset/Total assets
COMta	Total assets	Total assets of a company
COMEPS	Earnings per share	Total equity/Shares of common stock
COMOCFPS	Operating cash flow per share	Operating net cash flow/Total shares
COMTAGR	Total assets growth rate	(Final total assets − Initial total assets)/Initial total assets
COMccr	Capital accumulation rate	(Final stockholders' equity − Final stockholders' equity last year)/ Final stockholders' equity last year
COMrgr	Revenue growth rate	(This year's revenue − Last year's revenue)/Last year's revenue
COMTra	Capital turnover rate	Revenue/Average total assets

growth rate, capital accumulation rate, revenue growth rate, and total asset turnover are also taken into overall consideration in this study [12]. By comprehensively analyzing each index, the results become more convincing.

20.2.3 Theoretical Model

Data envelopment analysis (DEA), a vital analytical tool in the field of economy and management, is a kind of evaluation method based on efficiency and a kind of non-parametric method assessing the technique effectiveness of the same decision-making units through a mathematical programming model. Its principal advantage is that multiple input and output variables can be considered at the same time. This research, hence, adopts the DEA model for analysis. To present the original data structure in a more concise way, principal component analysis (PCA) seeks to extract the main components, between which there is no correlation, from indicators associated with each other. By PCA variable dimension can be reduced, which, in turn, facilitates weakening the effect of variable error on DEA analysis results.

As the theoretical model presented in Fig. 20.1, we set a serious of attribute variables of female executives which can comprehensively analyzes the proportion and diverse traits of female executives, and by uses PCA, we could get the principal components of these attribute variables, so is the setting of the index variables of firm performances. The principal components make it more convenient and representative to analysis the link between female executives and firm performances by DEA. Based on this, a super efficiency DEA is also needed to seek how the female

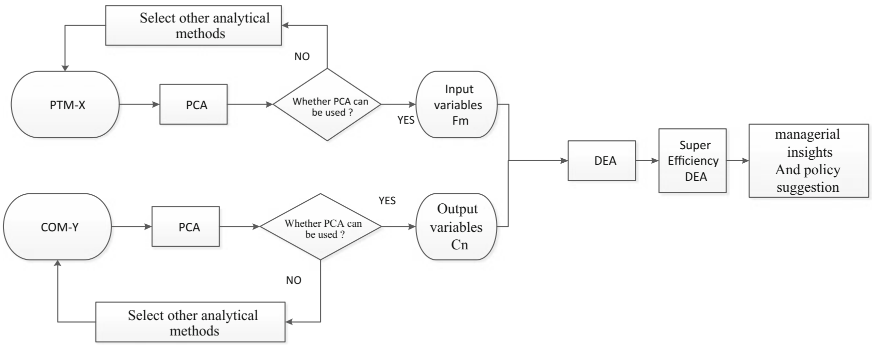


Fig. 20.1 The theoretical model

executives impact the firm performances before drawing conclusions and providing advice.

20.3 Empirical Analysis

20.3.1 Descriptive Analysis and PCA Processing of Samples

It can be observed from the sample data that there are twenty-one cultural enterprises with female executives, accounting for 77.78 % of the total numbers. Tables 20.3 and 20.4 illustrate the analysis of the data available.

Next, each index variable of female executives is processed by using PCA method, respectively. The results can be found in Table 20.5.

The explanation degree is 85 % when $m = 5$, generating five values of F_m. They, according to the corresponding coefficient matrix, can be respectively defined as:

Table 20.3 Correlation analysis of attribute variables of female executives

	FTMrate	FTMage	FTMceo	FTMtime	FTMmajor	FTMPT	FTMedu	FTMexper	FTMfamily
FTMrate	1								
FTMage	−0.271	1							
FTMceo	0.303	−0.014	1						
FTMtime	0.206	−0.12	−0.074	1					
FTMmajor	0.116	−0.101	−0.055	−0.372	1				
FTMPT	0.497*	−0.003	−0.026	0.123	0.212	1			
FTMedu	−0.006	−0.168	0.159	−0.522*	0.068	−40.435	1		
FTMexper	0.307	−0.228	0.392	−0.235	0.651**	0.158	0.018	1	
FTMfamily	0.083	−0.303	−0.306	−0.037	−0.159	0.287	−0.156	−0.112	1

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Table 20.4 Correlation between corporate performance indicators

COMnet	COMROA	COMdet	COMTAGR	COMEPS	COMOCFPS	COMtgr	COMccr	COMrgr	COMTra
1									
0.569*	1								
0.478	−0.428	1							
0.1	0.159	0.055	1						
0.357	0.778**	−0.425	0.1	1					
0.04	0.115	−0.093	0.315	−0.194	1				
0.327	0.252	0.129	0.251	0.164	0.104	1			
0.524*	0.394	0.222	0.357	0.234	0.095	0.797**	1		
0.266	−0.032	0.343	0.08	−0.037	−0.241	0.643**	0.534*	1	
−0.079	0.103	−0.073	0.256	0.091	0.076	−0.207	0.101	0.041	1

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Table 20.5 PCA analysis results of female executive variables

Component	Initial eigenvalues			Extraction sums of squared loading		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.2	24.44	24.44	2.2	24.44	24.44
2	2.02	22.44	46.88	2.02	22.44	46.88
3	1.372	15.245	62.125	1.372	15.245	62.125
4	1.27	14.111	76.236	1.27	14.111	76.236
5	0.87	9.663	85.899	0.87	9.663	85.899
6	0.636	7.067	92.965			
7	0.309	3.433	96.398			
8	0.17	1.889	98.287			
9	0.154	1.713	100			

Extraction method: principal component analysis

management qualification of female executives, their study and part-time job experience, the status of female executives in an enterprise, their age and life experience, as well as their work and learning ability, which can be expressed as:

$$F_1 = 0.545\,X_1 - 0.321\,X_2 + 0.468\,X_3 - 0.356\,X_4 + 0.727\,X_5 + 0.317\,X_6 + 0.214\,X_7 + 0.874\,X_8 - 0.120\,X_9, \tag{20.1}$$

$$F_2 = 0.526\,X_1 - 0.222\,X_2 - 0.155\,X_3 + 0.621\,X_4 - 0.111\,X_5 + 0.744\,X_6 - 0.706\,X_7 - 0.014\,X_8 + 0.468\,X_9, \tag{20.2}$$

$$F_3 = 0.205\,X_1 + 0.386\,X_2 + 0.604\,X_3 + 0.432\,X_4 - 0.262\,X_5 - 0.056\,X_6 - 0.204\,X_7 + 0.044\,X_8 - 0.691\,X_9, \tag{20.3}$$

$$F_4 = 0.334\,X_1 + 0.659\,X_2 - 0.327\,X_3 - 0.185\,X_4 + 0.479\,X_5 + 0.291\,X_6 - 0.457\,X_7 + 0.130\,X_8 - 0.209\,X_9, \tag{20.4}$$

Table 20.6 PCA processing results of firm performance variables

Component	Initial eigenvalues			Extraction sums of squared loading		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	3.108	31.084	31.084	3.108	31.084	31.084
2	2.138	21.379	52.462	2.138	21.379	52.462
3	1.464	14.64	67.102	1.464	14.64	67.102
4	1.084	10.836	77.937	1.084	10.836	77.937
5	1.041	10.412	88.35	1.041	10.412	88.35
6	0.603	6.028	94.378			
7	0.295	2.952	97.33			
8	0.184	1.838	99.168			
9	0.079	0.787	99.955			
10	0.004	0.045	100			

Extraction method: principal component analysis

$$
\begin{aligned}
F_5 =&0.238\,X_1 +0.436\,X_2 +0.255\,X_3 -0.437\,X_4 -0.272\,X_5 +0.357\,X_6 \\
&+ 0.205\,X_7 \;\; -0.219\,X_8 +0.274\,X_9\,. \qquad (20.5)
\end{aligned}
$$

Similarly, index variables of firm performance are processed through PCA method, and the analysis results are listed in Table 20.6.

In a similar vein, the explanation degree is 88.35 % when $S = 5$, generating five values of, namely the principal components of firm performance evaluation.

$$
\begin{aligned}
C_1 =&0.728\,Y_1 +0.625\,Y_2 +0.183\,Y_3 +0.393\,Y_4 +0.481\,Y_5 +0.069\,Y_6 \\
&+ 0.796\,Y_7 \;\; +0.890\,Y_8 +0.580\,Y_9 +0.044\,Y_{10}, \qquad (20.6)\\
C_2 =&0.031\,Y_1 +0.720\,Y_2 -800\,Y_3 +0.054\,Y_4 +0.728\,Y_5 +0.117\,Y_6 \\
&- 0.269\,Y_7 \;\; -0.165\,Y_8 -0.534\,Y_9 +0.212\,Y_{10}, \qquad (20.7)\\
C_3 =&- 0.202\,Y_1 -0.109\,Y_2 -0.017\,Y_3 +0.694\,Y_4 -0.316\,Y_5 +0.754\,Y_6 \\
&+ 0.009\,Y_7 \;\; +0.129\,Y_8 -0.165\,Y_9 +0.466\,Y_{10}, \qquad (20.8)\\
C_4 =&- 0.381\,Y_1 -0.129\,Y_2 -0.175\,Y_3 +0.111\,Y_4 +0.114\,Y_5 -0.510\,Y_6 \\
&- 0.007\,Y_7 \;\; +0.076\,Y_8 +0.406\,Y_9 +0.659\,Y_{10}, \qquad (20.9)\\
C_5 =&0.518\,Y_1 +0.084\,Y_2 +0.255\,Y_3 +0.515\,Y_4 +0.030\,Y_5 +0.064\,Y_6 \\
&- 0.130\,Y_7 \;\; -0.190\,Y_8 -0.171\,Y_9 +0.447\,Y_{10}\,. \qquad (20.10)
\end{aligned}
$$

In the DEA model, the value of an input and output variable is not less than zero. To meet these requirements, the paper performs data normalization of and before substituting variables into the DEA model. The processing formula is: $\mathrm{x}_i^{'} = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}$. The computation results are not affected after normalization.

20.3.2 DEA Analysis

(1) DEA Solving Results The DEA model of any decision making unit (DMU) is h_0:

$$\max\ h_0 = \mu^T C_0$$
$$\text{s.t.}\begin{cases} \mu^T C_j - \omega^T F_j \le 0; \\ \omega^T F_0 = 1 \\ \mu \ge 0; \omega \ge 0; j = 1, 2, \cdots, n \end{cases}$$

By substituting the five respective output and input variables obtained from seventeen DMUs above into the DEA equation and solving it, the paper has the following results in Table 20.7.

It is manifest from Table 20.7 that among the seventeen enterprises, the computation result of thirteen companies is equal to 1, constituting 76.47 % of the total number; nevertheless, among the four companies not achieving the effectiveness, the result of three firms is larger than 0.6, and the effect of PCA process on result accuracy cannot be excluded. Therefore, analysis results of the DEA model preliminarily reveal that, from the perspective of scale efficiency, gender diversity of enterprise senior managers has a positive impact on the enhancement of firm performance. To further explore this issue, the super efficiency DEA process is performed.

(2) Super Efficiency DEA Super efficiency DEA model is established, and the super efficiency DEA model of a decision making unit k is expressed as follows:

$$\min \theta_k$$
$$\text{s.t.}\begin{cases} \sum\limits_{\substack{\mathrm{j=1} \\ j \ne \mathrm{k}}}^{17} F_{ij}\omega_j \le \theta_k F_{ij} \\ \sum\limits_{\substack{\mathrm{j=1} \\ j \ne \mathrm{k}}}^{17} C_{ij}\omega_j \ge C_{ij} \\ \omega_j \ge 0; \quad j = 1, 2, \cdots, 17; \quad i = 1, 2, \cdots, 5. \end{cases}$$

Table 20.7 DEA solving results

FTM	Crste	FTM	Crste
1	1	10	0.867
2	0.604	11	1
3	1	12	1
4	1	13	1
5	1	14	1
6	0.676	15	1
7	1	16	1
8	0.425	17	1
9	1		

Table 20.8 Solving results of super efficiency DEA

θ	Value	θ	Value
1	1.244204	10	0.8665777
2	0.6043535	11	1.12711
3	1.219363	12	5.424586
4	2.646864	13	1.491909
5	115.7456	14	1.883047
6	0.6758432	15	1.56235
7	2.664343	16	2.650614
8	0.425403	17	663.7133
9	1.693501		

Table 20.9 Sorting enterprises with $\theta > 1$

DMU number	θ value	Dual price
17	663.7133	Input factors 1, 2, 5
5	115.7456	Input factors 1, 4
12	5.424586	Input factors 1, 4
7	2.664343	Input factors 1, 2
16	2.650614	Input factors 1, 3, 4
4	2.646864	Input factors 1, 5
14	1.883047	Input factors 1, 2, 3
9	1.693501	Input factors 1, 3, 5
15	1.56235	Input factors 1, 2, 3
13	1.491909	Input factors 1, 2, 3, 5
1	1.244204	Input factors 1, 4, 5
3	1.219363	Input factors 1, 2, 4
11	1.12711	Input factors 1, 2, 3

LINGO is utilized to solve the super efficiency DEA, the results of which are illustrated in Table 20.8.

It is evident from the solving results Table 20.8 that among seventeen companies the of thirteen firms is larger than 1. Sort them numerically in descending order so that Table 20.9 is obtained.

The DEA results of the thirteen enterprises above are efficient, proving the positive impact of female executives and gender diversity of senior managers on the enhancement of firm performance. Through further analysis of the solving results of this super efficiency DEA model, the impacts of female executives' various factor variables on firm performance can be examined according to the corresponding input factors of each enterprise listed in Table 20.9. Taking DMU7 in the previous table for example, it is Hualu Baina media company. It can be seen from Table 20.9 that this company can improve its performance through adjusting input factors 1 and 2. Likewise, the analysis of F_1 and F_2 reveals that Hualu Baina can enhance its firm performance by increasing the proportion of female executives and the percentage of part-time female executives, as well as lengthening their serving time.

20.3.3 Suggestions

The research results reveal that in enterprises from the cultural creative industry, the proportion of female executives plays a positive role in improving firm financial performance. Considering the situation of Chinese enterprises from cultural creative industry, the paper puts forward the following suggestions:

(1) The proportion of female executives and executives can be properly increased. This study finds that enterprises with a higher proportion of women has a correspondingly higher firm performance. Therefore, an enterprise can increase its production and product value and enhance its performance by making full use of the participation of female executives.

(2) The internal promotion system of an enterprise should be optimized. Allowing an increasingly large number of female executives to participate in the process of enterprise management, decision-making, and supervision and implementation of all costs can not only provide more opportunities for these capable female managers, but promote the enterprise value creation, improving its firm financial performance as well.

(3) The research shows that factors such as female executives' education, professional background, management experience, and part-time jobs, etc. can improve their impacts on firm performance, and that enhancing their ability has positive significance for raising the level of enterprise management decisions. Hence, female executives should be entitled to equal training opportunities, thereby improving their personal ability.

(4) Thanks to the female characteristics such as excellent communication skill, strong affinity, and so forth, female executives can perform well in the enterprise management decision making and execution process. Enterprises, hence, should afford female executives opportunities to participate in the decision-making and management process and actively adopt their opinions and suggestions, thereby enabling them to play a greater role in enterprise management and decision making.

20.4 Conclusion

Taking enterprises from the cultural creative industry in China as samples, the paper analyzes the impact of gender diversity of board members on firm performance. To be specific, by applying PCA and super efficiency DEA methods, the impact of female executives on firm performance is examined. Research variables comprehensively cover various aspects of female executives' attributes and different indicators of firm performance. Research results show that the DEA of 76.47 % of companies is effective, indicating the positive impacts of female executives on enterprise management and the positive effects of gender diversity of managers on the enhancement of firm performance. According to the LINGO solving results through super efficiency DEA, researchers not only can observe the impact degree of female executives on firm performance, but, through analyzing the corresponding input factors, they can explore the approaches to enhancing firm performance by adjusting gender diversity of managers in a company. As illustrated in Table 20.9, Firm performance can be improved by increasing input factor 1 in each enterprise with effective DEA. That is, Firm performance can be further enhanced by increasing the proportion of female executives, improving their professional background and management experience.

The cultural creative industry is considered as one of the most dynamic industries in China; therefore, the study of gender diversity of managers in this very industry has great practical significance. This paper adopts the PCA and DEA methods to explore the impact of female executives on firm performance, advancing the research methods in this field by examining multiple factors comprehensively. It may contribute to the study of the relationship between gender diversity in enterprise management stratum and firm performance.

20.5 Limitations and Suggestions for Future Research

In the first place, this article principally underlines enterprises in cultural creative industry, failing to comprehensively examine all industries in the market. It, therefore, has certain limitations, and the research results, to some extent, are not very representative. Scholars in the future may examine a wide range of industries, further studying the effect of gender diversity on firm management.

In the second place, this study largely examines the impact of female executives on firm financial performance, considering few indicators of other aspects of the enterprise. Future scholars may concern more about firm social performance and other social effects, thereby making the study more realistic and convincing.

Last, from the perspective of research methods, this paper needs more number of attribute variables of female executives or every indicator of an enterprise, the division of which is not as detailed and specific as possible, not fully reflecting the superiority of research methods. In future experiments, researchers may further adjust the variables, which, in turn, is conductive to obtaining more convincing findings and results, better revealing the effect of gender diversity of managers on firm management, and providing more realistic guidance.

Acknowledgments We would like to acknowledge Sichuan University Basic Fund for Research Project (project No. skqy 01229) for supporting us with the paper. And great gratitude to Liming Yao from Business School, Sichuan University for his many suggestions and supporting.

References

1. Adams RB, Ferreira D (2009) Women in the boardroom and their impact on governance and performance. J Financ Econ 94(2):291–309
2. Ahern KR, Dittmar AK (2012) The changing of the boards: the impact on firm valuation of mandated female board representation. Q J Econ 127(1):137–197
3. Campbell K, Mínguez-Vera A (2008) Gender diversity in the boardroom and firm financial performance. J Bus Ethics 83(3):435–451
4. Carter DA, D'Souza F et al (2010) The gender and ethnic diversity of us boards and board committees and firm financial performance. Corp Gov: Int Rev 18(5):396–414
5. Dezső CL, Ross DG (2008) 'Girl power': female participation in top management and firm performance. University of Maryland Robert H Smith School of Business
6. Haslam SA, Ryan MK et al (2010) Investing with prejudice: the relationship between women's presence on company boards and objective and subjective measures of company performance. Br J Manag 21(2):484–497
7. He J, Huang Z (2011) Board informal hierarchy and firm financial performance: exploring a tacit structure guiding boardroom interactions. Acad Manag J 54(6):1119–1139
8. Joecks J, Pull K, Vetter K (2013) Gender diversity in the boardroom and firm performance: What exactly constitutes a "critical mass?". J Bus Ethics 118(1):61–72
9. Krishnan GV, Parsons LM (2008) Getting to the bottom line: an exploration of gender and earnings quality. J Bus Ethics 78(1–2):65–76
10. Krishnan HA, Park D (2005) A few good womenłon top management teams. J Bus Res 58(12):1712–1720
11. Lindstädt H, Wolff M, Fehre K (2011) Frauen in führungspositionen-auswirkungen auf den unternehmenserfolg. German Federal Ministry of Family, Senior Citizens, Women and Youth vol. 8, p 2011
12. Liu Y, Wei Z, Xie F (2014) Do women directors improve firm performance in China? J Corp Financ 28:169–184
13. Mahadeo JD, Soobaroyen T, Hanuman VO (2012) Board composition and financial performance: uncovering the effects of diversity in an emerging economy. J Bus Ethics 105(3):375–388
14. Martín-Ugedo JF, Minguez-Vera A (2014) Firm performance and women on the board: evidence from spanish small and medium-sized enterprises. Fem Econ 20(3):136–162
15. Miller T, Triana CM (2009) Demographic diversity in the boardroom: mediators of the board diversity-firm performance relationship. J Manag Stud 46(5):755–786
16. Smith N, Smith V, Verner M (2006) Do women in top management affect firm performance? A panel study of 2,500 Danish firms. Int J Product Perform Manag 55(7):569–593
17. Welbourne TM (1999) Wall street likes its women: an examination of women in the top management teams of initial public offerings. CAHRS Working Paper Series, p 106

Chapter 21
Research on the Technology Transfer Efficiency Evaluation in Industry-University-Research Institution Collaborative Innovation and Its Affecting Factors Based on the Two-Stage DEA Model

Yuanchun Yu, Xin Gu and Yijun Chen

Abstract The traditional technical efficiency measurement regards the technology transfer system as a "black box" and doesn't penetrate the internal operation mechanism of the system. This paper opens the technology transfer system "black box" of industry-university-research institution (IUR) collaborative innovation, researches the internal structure of the system, and deconstructs the system into two stages: technology innovation stage and industrial value creation stage. On this basis, this paper calculates the technology transfer efficiency based on the two-stage DEA model. The result shows that the overall technology transfer efficiency in IUR collaborative innovation is low, and the bottlenecks for improving the technology transfer efficiency are different for different provinces. Through analyzing the internal and external factors of the system, this paper finds that the good cooperative relationship between enterprises and scientific research institutions can improve the efficiency of technology transfer. Refer to environmental factors, the government supports, the market competition and the demand for new products have positive impact on the efficiency of technology transfer.

Keywords Industry-university-research institution collaborative innovation · Technology transfer · Two-stage DEA

Y. Yu (✉) · X. Gu
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: yuanchun1981@163.com

Y. Yu
School of Economy and Management, Sichuan University of Science and Engineering, Chengdu 610064, People's Republic of China

Y. Chen
School of Economy and Management, Sichuan University of Science and Engineering, Zigong 643000, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_21

21.1 Introduction

The industry-university-research institution (IUR) technology transfer is an effective way of integrating the innovation resources of the universities, the research institutions and the enterprise, and promoting scientific achievements transformation. The technology transfer efficiency can reflect the innovation the status quo of resources utilization in the universities, the research institutions and the enterprises, the market prospect and the business process adaptability of technical innovation achievement. The researchers have paid much attention to the technology transfer, but most of researchers regard the technology transfer as a “black box”. They analyze the technology transfer efficiency by researching the overall input and output of the system, ignoring the inner structure and operation mechanism of the system. The efficiency evaluation results can’t reflect the development status and existing problems of the IUR technology transfer. This paper tries to open the UIR technology transfer “black box”, study the internal input-output mechanism, evaluate the IUR cooperative technology transfer efficiency by adopting network DEA method, and analyzes the internal and environmental factors of technology transfer system. On this basis, this paper analyzes the factors that affect the efficiency of the URI technology transfer in order to put forward suggestions for improving the UIR technology transfer.

21.2 Literature Review

Technology transfer involves the researchers, technology transfer offices, enterprises, etc. [1], and refer to a large number of activities including innovation resource accumulating, collaborative innovation researching, technology licensing, consulting services, and new technology commercializing, etc. [2]. Therefore, the UIR technology transfer efficiency evaluation should employ an integrated approach. Parametric approaches [3, 4], and nonparametric approaches [5, 6] are adopted by the empirical studies on the efficiency evaluation of UIR technology transfer. The evaluation indexes refer to the main parties participating in the technology transfer process such as the government, universities, enterprises, etc. [7] or involve the critical activities playing important roles in technology transfer process [2]. The results show that the overall technology transfer efficiencies of most regions are low and the differences are great among the regions.

Although most of the studies regard the technology transfer system as a “black box”, and analyze the researching the technology transfer efficiency by researching the overall input-output relationship of the system, ignoring the internal operation mechanism, some researchers deconstruct the internal process of the UIR technology transfer and analyze the operation status s of each link. Tursby and Tursby [6] believed that the UIR technology transfer consists of three input-output processes: the invention disclosure, the patent applications and the patent licensing. Tursby and

Tursby argued that the effective management of the each transfer stage is crucial to the successful URI technology transfer. Mei et al. [8] divided the UIR technology transfer into two stages: research innovation and value creation based on Tursby and Tursby's research achievement.

The researchers mainly analyze the factors affecting the URI technology transfer efficiency from two aspects: the internal and the external environment. Concerning the internal factors, the high commitment and the strong participation willingness of enterprises [9], and the excellent research achievements and strong internationalization consciousness of the universities and research institutions [10] can improve the successful probability of technology transfer. Meanwhile, the innovation ability [11] and the entrepreneurial orientation of the universities and the research institutions [5], the good communication among the organizations [12], the synergy of the different targets of different organizations [13] have positive role playing in technology transfer. Concerning the external environment factors, the researchers believe that the technology transfer platforms [14], the government supports [13], the intellectual property protection [15], financing service system [16] and so on have important effects on the UIR technology transfer efficiency.

According to the literary review, most of the researches on UIR technology transfer efficiency regarded the technology transfer system as a "black box", ignoring the internal operation mechanism analyzing. Tursby and Tursby [6] deconstructed the UIR technology transfer "black box" without considering the relationship between the various subsystems. Mei et al. [9] took the internal links of the system, but its perspective is mainly on the universities' ability. Concerning on the studies of the factors affecting the transfer efficiency, the researchers analyze the factors of the internal and external environment of the technology transfer system. However, the studies are not systemic and don't pay attention to the interaction between environmental factors and the internal factors of the system. The UIR technology transfer is a complex system involving the universities, the research institutions and the government, so only the internal operation of the technology transfer system is deconstructed, and the influencing factors of internal and external factors are explored can we put forward some useful suggestions on improving the transfer efficiency.

21.3 Evaluation of the URI Technology Transfer Efficiency

21.3.1 Deconstruction of the URI Technology Transfer "Black Box"

Draws on the research of Mei et al. [9], this paper divides the URI technology transfer process into two stages: the technology innovation stage and the industrial value creation stage (see Fig. 21.1). The core task in the technology innovation stage is to

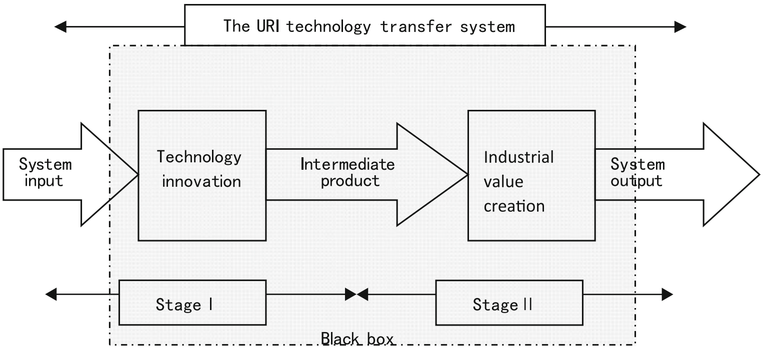


Fig. 21.1 The deconstruction of the URI technology transfer black box

technicalize the knowledge innovation achievements. The core task in the industrial value creation stage is to commercialize the technology innovation achievements. The higher the URI synergistic degree is, the better the technology innovation achievements meet the enterprises' requirements, the more maturity the technology is, the better the market prospects promise, and the higher chances for successful technology transfer are.

The foreign literatures on technology transfer are mostly based on patents analysis. With the improvement of the patent system and the enhancement of the intellectual property protection consciousness, more and more technology innovation achievements are represented in the form of patents, and more and more researchers turn to research technology transfer from the patent perspective in recent years [17, 18]. Therefore, this paper also selects the technology transfer indexes from the patent perspective. In the stage of technology innovation, because of the personnel advantages on the knowledge innovation ability and experience, the universities and the research institutions mainly input the human resources into the system; the enterprises mainly input the capital. Then the research staff of the universities and the research institutions and the R&D found of the universities and the research institutions getting from the enterprises and the government are the input indexes in the first stage. The number of the authorized patent of the universities and the research institutions is the output index, which is also the input index in the second stage. In the industrial value creation stage, the diffusion of the technique innovation achievements is the mainly focus. The researchers mainly adopt the number of patents transfer and licenses as the main output indicators. Because Siegel et al. [4] deemed that the number of patent licenses alone is difficult to reflect the relative importance of the patent licensing. Therefore, this paper adopts the number of patents licenses and the patents licensing revenue as the output indicators in second stages.

21.3.2 Mode Definition

Based on the analysis of the URI technology transfer process, this paper utilizes the two-stage DEA model prompted by Chen to evaluate the efficiency. According to the model, the production process is composed of two pre- and post- linking stages. The intermediate product of the system is the output of the first stage and at the same time it's the input of the second production stages. Based on the idea that the intermediate output should become more flexible in order to optimize the efficiency of the two stages of the system, Chen et al. assumes that the relative importance of the two stages of the production process to the overall system is w_1 and w_2 who's size is decided by the production scale of its' stage. The specific calculation formula is as shown in Eqs. (21.1), (21.2):

$$w_1 = \left(\sum_{i=1}^{m} v_i x_{ik} \middle/ \left(\sum_{i=1}^{m} v_i x_{ik} + \sum_{j=1}^{n} u_j y_{jk} \right) \right), \tag{21.1}$$

$$w_2 = \left(\sum_{j=1}^{n} \mathrm{u_j y_{jk}} \middle/ \left(\sum_{i=1}^{m} \mathrm{v_i x_{ik}} + \sum_{j=1}^{n} \mathrm{u_j y_{jk}} \right) \right). \tag{21.2}$$

Thus the overall efficiency of the system is $h_k = w_1 h_k^1 + w_2 h_k^2$, that is:

$$h_k = \frac{\sum_j^n u_j y_{jk} + \sum_p^q t_p z_{jk}}{\sum_i^n v_i^1 x_{ik}^1 + \sum_j^n u_j^1 y_{jk}^1}, \tag{21.3}$$

h_k^1 and h_k^2 are the efficiency of the two production stages of the decision making unit k respectively, x_{ik} is the input vector for the first production stage, y_{jk} is output vector of the first stage and the input vector of the second stage, z_{jk} is the output vector of the second stage. After the Charnes and Cooper transformation, the two-stage DEA model is as follow (Eq. (21.4)):

$$h_k = \mathrm{Max} \sum_{p=1}^{q} s_j z_{jk} + \sum_{j=1}^{n} r_j y_{jk} \tag{21.4}$$

$$s.t. \begin{cases} \sum_{i=1}^{m} w_i x_{ik} + \sum_{j=1}^{n} r_j y_{jk} = 1 \\ \sum_{j=1}^{n} r_j y_{jk} - \sum_{i=1}^{m} w_i x_{ik} \le 0 \\ \sum_{p=1}^{q} t_j z_{jk} - \sum_{j=1}^{n} r_j y_{jk} \le 0. \end{cases}$$

According to Eq. (21.4), it turns out that $w_1 = \sum_{i=1}^{m} w_i x_{ik},\ w_2 = \sum_{j=1}^{n} t_j y_{jk}$, the size of the w_1 and w_2 determined the solution priority of the two stages [19]. If

$w_1 > w_2$, then h_k^1 is given to the solution priority, and it is calculated from Eq. (21.5)

$$\max h_k^1 = \frac{\sum_{j=1}^{n} u_j y_{jk}}{\sum_{i=1}^{m} v_i x_{ik}}$$
$$s.t. \begin{cases} \dfrac{\sum_{j=1}^{n} uy}{\sum_{i=1}^{m} vx} \le 1 \\ \dfrac{\sum_{p=1}^{q} t_p z_{jk}}{\sum_{j}^{n} u_j y_{jk}} \le 1 \\ h_k = \dfrac{\sum_{j}^{n} u_j y_{jk} + \sum_{p}^{q} t_p z_{jk}}{\sum_{i}^{n} v_i x_{ik} + \sum_{j}^{n} u_j y_{jk}} \\ u_j \ge 0, v_i \ge 0, t_p \ge 0, k = 1, \cdots, n \end{cases} \tag{21.5}$$

If $w_2 > w_1$, then the stage two is given the priority, the efficiency h_k^2 of the stage two is determined by the following model (Eq. (21.6)):

$$\max h_k^2 = \frac{\sum_{p=1}^{q} t_p z_{jk}}{\sum_{j=1}^{n} u_j y_{jk}}$$
$$s.t. \begin{cases} \dfrac{\sum_{j=1}^{n} u_j y_{jk}}{\sum_{i=1}^{m} v_i x_{ik}} \le 1 \\ \dfrac{\sum_{p=1}^{q} t_p z_{jk}}{\sum_{j=1}^{n} u_j y_{jk}} \le 1 \\ h_k = \dfrac{\sum_{j}^{n} u_j y_{jk} + \sum_{p}^{q} t_p z_{jk}}{\sum_{i}^{n} v_i x_{ik} + \sum_{j}^{n} u_j y_{jk}} \\ u_j \ge 0, v_i \ge 0, t_p \ge 0, k = 1, \cdots, n. \end{cases} \tag{21.6}$$

21.3.3 Data Sources, Time Lag Discussion and Empirical Results

(1) Data Sources

Because of the missing data of Tibet Province, this paper selects China's 30 provinces without Tibet as the decision-making units to analyze the URI technology transfer efficiency. With regard to the data sources, the University's R&D funds getting from the government and the enterprise, the University R&D personnel, the number of University licensing patents, the number of the transfer patents and the licensing income are from the Sci-Tech Statistical Data of the National Colleges and Universities. The data of research institutions R&D funds getting from the government and enterprises, the number of transfer and licensing patents and the licensing income are derived from the China Science and Technology Statistics Yearbook, and the data of the research institutions licensing patents are from the State Intellectual Property Office website.

(2) Time Lag Discussion

The inputting and the outputting of technology transfer system are difficult to occur in the same year, thus the time-delay between the inputting and outputting should be considered. Concerning the time lag of the whole system, Markman [20], Llor [21] find that it will take 4 years to complete the process from the innovation inputting to the patent technology transferring. After testing 3, 4, 5 years of lag period, Chen et al. [22] find that the technology efficiency is accordance with the actual case better with the 4 years of time lag. Concerning the sub-stage time lag of the system, Hausman et al. find a 2-year lag between R&D inputting and patents applying [23]. Liu and Chen's [24] study shows that the impact of R&D funding and technology personnel on innovation output will be maximum in the lag period of 2 years. Based on the literature above this paper takes 4 years as the period of the time lag of the whole system, and takes two years as the sub-stage time lag period. Then this paper adopts the input data of the research and development founding and the number of the researchers in 2006–2009 years, the intermediate product data of the number of the patents license in 2008–2011 years, and the final output of the patent transfer, licensing number and revenue in 2010–2013 years.

(3) Empirical Results Analysis

The results of the model (see Table 21.1) show that the differences of the UIR technology transfer efficiency among the provinces are great. Firstly, the differences of the overall technology transfer efficiency among the provinces are great. Beijing has been in the production frontier during 2010–2013; the overall technology transfer efficiency of Qinghai Province is 0 which is the lowest among the regions. The development trends of the regional technology transfer efficiency are also different: the overall efficiency of Beijing, Jiangsu and other provinces have remained relatively high level; the efficiency of Inner Mongolia, Jiangxi, Yunnan, Qinghai and other provinces have been at a low level; the efficiency of Shanghai, Hubei, and other provinces are relatively stable, while the efficiencies of Guangdong, Shandong, Ningxia, Liaoning and other provinces present the big fluctuation. Secondly, the bottle neck restraining the growth of the overall efficiency is different. The efficiency of Shanghai, Jiangsu, Zhejiang, Sichuan and other provinces in value creation stage is relatively high, but the low efficiency in technological innovation has restricted the increasing of the overall technology transfer efficiency; the relative low technology transfer efficiency in industrial value creation stage of Hainan, Ningxia, Qinghai, Guizhou and other provinces restrains the increasing of the overall technology transfer efficiency; both the overall efficiency and the sub-stages efficiency of Inner Mongolia, Jilin, Jiangxi, Yunnan and other provinces are inefficient.

Table 21.1 The URI technology transfer efficiency

Regions	2010			2011			2012			2013		
	Stage one	Stage two	The over-all	Stage one	Stage two	The over-all	Stage one	Stage two	The over-all	Stage one	Stage two	The over-all
Beijing	1	1	1	1	1	1	1	1	1	1	1	1
Tianjin	0.211	0.722	0.152	0.257	0.703	0.181	0.172	1	0.172	0.116	1	0.116
Hebei	0.225	0.903	0.203	0.283	0.453	0.128	0.237	1	0.237	0.247	1	0.247
Shanxi	0.234	0.55	0.129	0.291	0.286	0.083	0.158	0.792	0.125	0.227	0.54	0.123
Inner Mongolia	0.578	0.014	0.008	0.725	0.025	0.018	0.383	0.014	0.005	0.274	0	0
Liaoning	0.112	1	0.112	0.999	1	0.999	0.135	1	0.135	0.153	1	0.153
Jilin	0.175	0.362	0.063	0.21	0.194	0.041	0.086	0.244	0.021	0.109	0.384	0.042
Heilongjiang	0.15	0.458	0.069	0.198	0.395	0.078	0.162	1	0.162	0.083	0.854	0.07
Shanghai	0.282	1	0.282	0.578	1	0.578	0.624	1	0.624	0.317	1	0.317
Jiangsu	0.465	1	0.465	0.614	1	0.614	0.694	1	0.694	0.646	1	0.646
Zhejiang	0.489	1	0.489	0.721	1	0.721	0.892	1	0.892	0.102	1	0.102
Anhui	0.228	0.944	0.215	0.304	0.739	0.225	0.3	1	0.3	0.293	1	0.293
Fujian	0.321	1	0.321	0.516	0.321	0.166	0.191	0.636	0.121	0.205	0.759	0.156
Jiangxi	0.29	0.159	0.046	0.359	0.146	0.052	0.181	0.068	0.012	0.214	0.012	0.002
Shandong	1	1	1	0.987	1	0.987	0.573	1	0.573	0.202	1	0.202
Henan	0.192	0.408	0.078	0.228	0.203	0.046	0.172	0.452	0.078	0.349	1	0.349
Hubei	0.397	1	0.397	0.572	1	0.572	0.527	1	0.527	0.42	1	0.42
Hunan	0.193	0.514	0.099	0.233	0.369	0.086	0.102	0.511	0.052	0.111	0.706	0.078
Guangdong	0.76	1	0.76	0.431	1	0.431	0.339	1	0.339	0.084	1	0.084
Guangxi	0.379	0.458	0.174	0.334	0.437	0.146	0.219	1	0.219	0.326	1	0.326
Hainan	1	1	1	1	1	1	1	0.418	0.418	1	0	0
Chongqing	0.316	1	0.316	0.365	1	0.365	0.297	1	0.297	0.305	1	0.305
Sichuan	0.094	1	0.094	0.098	0.971	0.095	0.368	1	0.368	0.207	1	0.207
Guizhou	0.705	0.043	0.03	0.952	0.034	0.032	1	1	1	0.702	0.058	0.041
Yunnan	0.262	0.315	0.083	0.307	0.232	0.071	0.168	0.332	0.056	0.166	0.287	0.048
Shaanxi	0.081	0.722	0.058	0.1	0.657	0.066	0.252	1	0.252	0.112	1	0.112
Gansu	0.38	0.282	0.107	0.324	1	0.324	0.357	0.562	0.201	0.397	1	0.397
Qinghai	1	0	0	1	0	0	1	0	0	1	0	0
Ningxia	1	0	0	1	1	1	1	0	0	1	1	1
Xinjiang	1	0.127	0.127	0.656	0.381	0.25	0.992	0.455	0.451	0.944	0.218	0.206
Average	0.451	0.633	0.263	0.538	0.618	0.345	0.453	0.716	0.311	0.377	0.727	0.235

21.4 Analysis of the Factors Affecting the URI Technology Transfer

21.4.1 Variable Selection and Data Source

This paper selects the factors affecting the URI technology transfer in the system and in the environment. The factors in the system include the synergic relationship between the universities the research institutions and the enterprises. The factors associated with environment include the government supports, financial environment, market environment, intellectual property protection and other aspects. Concerning the cooperation between universities research institutions and enterprises in the system, this paper adopts the Li' method [12] to use the proportion of the R&D funds of the universities and the research institutions invested by enterprises to measure the cooperation degree. The ratio of regional Sci-Tech founds from the government is used to represent the government's support [25]. With regard to the financial environment, this variable is represented by the proportion of the Sci-Tech founds from the financial institutions [13]. The market competition is represented by the number of the enterprises in the region [26]. The demand for new products in the market is represented by the proportion of new products sales revenue in the enterprise product sales [27]. As to the intellectual property right (IPR) protection, this variable is represented by the amount of transactions in the provinces [28]. The data of Sci-Tech founds of the universities and research institutions invested by the enterprises, the regional Sci-Tech founds from the government and the technology market transactions volume is from "China Science and Technology Statistics Yearbook" and "the Sci-Tech Statistical Data of the National Colleges and Universities. The data of the number of enterprises in regions and the new products sales revenue is from "the China Industrial Enterprise Statistical Yearbook".

21.4.2 Model Definition and Empirical Results

According to various factors discussed above, this paper proposes a basic panel model. In order to reduce the number of heteroscedasticity, the model is taken logarithm, the specific model is shown in the Eq. (21.7):

$$\begin{aligned} \mathrm{lneff}_{it} = & \beta_1 \mathrm{lniuco}_{it} + \beta_2 \mathrm{lnirco}_{it} + \beta_3 \mathrm{lngov}_{it} + \beta_4 \mathrm{lnfin}_{it} + \beta_5 \mathrm{lncom}_{it} \\ & + \beta_6 \mathrm{lnneed}_{it} + \beta_7 \mathrm{lnp}_{it} + \varepsilon_{it}, \end{aligned} \tag{21.7}$$

where eff_{it} is the URI technology transfer efficiency of the i province in period t. Similarly $iuco_{it}$ is the coordination relationship between enterprises and research institutions. gov_{it} is the government support for technology transfer. fin_{it} is the financial environment. com_{it} is the market competition. need it is the market demand. lnp_{it}

Table 21.2 Empirical results

	(1)	(2)	(3)
lniuco	−0.745	−0.644	10.73***
	(−0.505)	(−0.492)	(−2.239)
lnirco	0.410***	2.012**	0.225
	(−0.159)	(−0.916)	(−0.15)
lngov	1.684*	1.705*	0.977*
	(−0.92)	(−0.893)	(−0.813)
lnfin	−0.112	−0.109	0.133
	(−0.423)	(−0.416)	(−0.38)
lncom	1.473***	1.428***	1.476***
	(−0.469)	(−0.454)	(−0.406)
lnneed	0.816*	0.715	0.178
	(−0.454)	(−0.443)	(−0.412)
lnip	−0.0776	0.87	2.455***
	(−0.262)	(−0.598)	(−0.542)
lnip* lniuco		0.265*	
		(−0.15)	
lnip* llnirco			1.805***
			(−0.349)

Note standard errors are in parentheses
*,**,*** are significant level at 10, 5 and 1 %, respectively

is the IPR protection. Because the lag time of the two stages is two years, the factors indexes are lagging behind the efficiency index for four years. Because the system efficiency of the DEA model is between 1 and 0, this paper adopts the Tob_{it} model, and the results are shown in Table 21.2: According to the regression results of the basic model (21.1), the regression coefficient of the coordination relationship between the enterprises and the universities can't pass the significance test. The egression coefficient of relationship between the enterprises and the research institutions is 0.410 ($p < 0.01$). The results indicate that the collaborative activities between the enterprises and research institutions have significant positive impact on the technology transfer, while the coordination relationship between the enterprises and the universities has no obvious effect on the extra-regional technology transfer. Compared with the universities, institutions are leaner and more flexible. The market consciousness of research institutions is stronger, and the experience of cooperating with enterprises is rich. Some research institutions are invested by the enterprises, which are easier to coordinate and communicate with the enterprise. Therefore, compared with universities, the cooperation relationship between research institutions and enterprises can promote the technology transfer technology better.

Concerning on the external environment of the technology transfer system, the regression coefficient of the government support is 1.684 ($p < 0.1$), which means that the government support has a positive effect on the technology transfer. Under the current scientific research systems, the government is the main investor and also the main risk taker of the technology transfer. With the government support, enterprises, universities and research institutions have stronger innovation motivation. Although the government support has passed the significance level test, but the significance level is not high, which means the government's financial aid is limited. The government can't substitute for the main body position of the enterprises in the process of the URI technology transfer, so provide policy supports and institutional guarantee maybe the more efficient support than founds.

The regression of the financial environment can't pass the significance test. China's venture capital market isn't fully developed. The banks are still the main financial institutions. In order to reduce the risk, the bank tends to give support to the technology transfer projects with strong strength, low risk, and promising market expectations, while the ones which need capital badly are often not supported.

Concerning on the market environment, the regression coefficients of the market competition level and the market demand are 1.473 ($p < 0.01$) and 0.816 ($p < 0.1$) respectively. The results indicate that the intense market competition and strong market demand for new products production have a positive impact on the URI technology transfer. The Market competition forces the enterprises to upgrade the technology, at the same time stresses the profit margins. Enterprises need to actively innovate, at the same time in the face of the tension of innovation resources. Coordinating with universities and research institutions can make the enterprise utilize more innovation resources. The positive impact of the market demand indicates that the market-driven URI cooperative system is forming.

Concerning on the IPR, the regression coefficient in the basic Eq. (21.1) doesn't pass the significant test. Interaction terms of the IPR with the coordination relationship between enterprises, universities (lnip* lniuco) and research institutions (lnip* llnirco) are placed in Eqs. (21.2) and (21.3) respectively on the base of Eq. (21.1). The regression coefficients of the Interaction terms lnip* lniuco and lnip* llnirco are positive, and all of them pass the significant test which indicate that strengthening the IPR can improve the technology transfer efficiency by improving the coordination relationship between enterprises, universities and research institutions.

21.5 Conclusion and Implication

In this paper, the internal operation mechanism of the URI technology transfer system is analyzed, and the technology transfer process is decomposed into two stages, the technological innovation and industrial value creation. The two-stage DEA method is applied to measure the overall efficiency and sub-stage the efficiency of the 30 provinces of China in 2010–2013. The results show that the URI technology transfer efficiency of each province is very different and the bottleneck restrains the increasing the efficiency of each province is also different.

Concerning on the factors affecting the technology transfer efficiency, the paper analyzes the factors in technology transfer system and in the environment. In the system, the coordination relationship between enterprise and research institutions has a positive impact on the technology transfer; the coordination relationship between enterprises and universities has not yet reached the threshold to effect the technology transfer efficiency. In terms of technology transfer system environment, the government support, the intense market competition and the strong market demand for new products can promote the URI technology transfer efficiency. At present, the financial environment has no impact on the URI technology transfer, and strengthening IPR can improve the efficiency of the technology transfer through promoting the cooperation between enterprises, universities and research institutions.

According to the research results above, this paper argues that: (1) the government should increase the financial support for the URI technology transfer, at the same time create a favorable policy environment; (2) introduce the venture capital funds to increase financial channels and reduce the technology transfer risk; (3) accelerate the construction of national unified technology transfer service platforms, strengthen the cross-region cooperation to give full play to the advantages of various provinces in different stages of technology transfer, and make up for the weak link.

Acknowledgments The research work is supported by Major Programs of National Social Science Funds of China (71571126) and is also supported by Department of Science and Technology of Sichuan Province Program (2014RK10).

References

1. Anderson TR, Daim TU, Lavoie FF (2007) Measuring the efficiency of university technology transfer. Technovation 27(5):306–318
2. Hsu DW, Shen YC et al (2015) Toward successful commercialization of university technology: performance drivers of university technology transfer in Taiwan. Technol Forecast Soc Chang 92:25–39
3. Antonelli C, Schumpeterian A (2015) Growth model: wealth and directed technological change. J Technol Transf 40(2):1–12
4. Siegel DS, Waldman D, Link A (2003) Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study. Res Policy 32(1):27–48
5. Kalar B, Antoncic B (2015) Assessing the relative performance of U.K. university technology transfer offices: parametric and non-parametric evidence. Technovations 36(37):1–11
6. Thursby JG, Thursby MC (2002) Who is selling the ivory tower? Sources of growth in university licensing. Manag Sci 48(1):90–104
7. Liao S, Xu S (2009) Analyzing on university-enterprise technology transfer efficiency and its influencing factors in China. Sci Sci Manag S&T 11:012
8. Ho MHC, Liu JS et al (2014) A new perspective to explore the technology transfer efficiencies in US universities. J Technol Transf 39(2):247–275
9. Bekkers R, Freitas IMB (2008) Analysing knowledge transfer channels between universities and industry: to what degree do sectors also matter? Res Policy 37(10):1837–1853
10. Rao K, Meng X et al (2011) University patent technology transfer in UK and its referential experiences. In: Forum on Science and Technology in China, vol 2, p 027
11. Yuan H (2004) On the obstacles and approaches of converting scientific researches intopositive results at universities. Res Educ Tsinghua Univ 3:016

12. Zhao D, Zuo M, Deng XN (2015) Examining the factors influencing cross-project knowledge transfer: an empirical study of it services firms in China. Int J Proj Manag 33(2):325–340
13. Rasmussen E, Moen Ø, Gulbrandsen M (2006) Initiatives to promote commercialization of university knowledge. Technovation 26(4):518–533
14. Tian M, Cao Z (2007) The successful technology transfer of Massachusetts institute of technology. Sci Sci Manag S&T 4:004
15. Intarakumnerd P, Charoenporn P (2015) Impact of stronger patent regimes on technology transfer: the case study of Thai automotive industry. Res Policy 44(7):1314–1326
16. Li W (2003) Analysis of the factors impacting on tech-transfer of Chinese universities and national research institutes. Sci Sci Manag S&T 24(6):48–51
17. Ye J, Yang Y et al (2015) Comparing efficiency of university technology transfers: evidence from chinese and U.S. university patents. Forum Sci Technol China 1:150–155
18. Li T (2014) Study on efficiency evaluation and cooperative governance of China's regional innovation. Ph.D. thesis, Huibei, University of Science and Technology of China
19. Peng Y, Chen S et al (2013) Efficiency based on the two-stage correlative DEA-Malmquist index on western regional technical innovation. Oper Res Manag Sci 22(3):162–168
20. Markman GD, Gianiodis PT et al (2005) Innovation speed: transferring university technology to market. Res Policy 34(7):1058–1075
21. Llor A (2007) Delay from patent filing to technology transfer: a statistical study at a major public research organization. Technovation 27(8):446–460
22. Chen K, Li X, Yang G (2014) A comparison of technology transfer efficiency of domestic and foreign universities: based on the DEA-Malmquist method. Sci Sci Manag S&T 35(7):98–106
23. Hall GH (1983) Patents and R&D: searching for a lag structure. NBER working paper
24. Liu Z, Chen X (2013) Evaluation of Chinese science parks on innovation efficiency-time lag effect based investigation. Chin J Manag 12(25):727–732 (in Chinese)
25. Yuan C, Gao J, Sun H (2014) The impact of local government support and regional market uncertainty on the efficiency of university technology transfer-evidence from chinese "211-project" universities. R&D Manag 25(3):10–17
26. Nickell SJ (1996) Competition and corporate performance. J Polit Econ 104:724–746
27. Chen Z, Yu X (2007) A study on impact of external environment on R&D input of enterprises: empirical analysis on panel data of Chinese industries. Sci Res Manag 28(2):78–84
28. Hui K, Wu Q, Hu Y (2012) The effects of intellectual property rights protection on technology innovation: empirical analysis based on technology trading market and provincial panel data in China. J Financ Econ 28(8):15–25

Chapter 22
Research on Fault Diagnosis for Air Drilling Based on an Improved PSO for Optimization of Fuzzy Neural Network

Dan Zhang, Tingting Zhu, Yiqing Lv, Jing Hou and Yue He

Abstract The air drilling technology, which is a new kind of drilling technology, has got a wide range of applications at home and abroad. Compared with conventional drilling technology, it has a large number of advantages, such as lower cost, faster drilling speed and less pollution. However, lots of questions like drilling tools out of operation frequently were exposed during the gas drilling which restricted the development of air drilling technology. Thus, it has great significance to hammer at studying the air drilling accident diagnostic techniques. The paper has a comprehensive introduction about air drilling principle and the cause of the accident in the process of air drilling. Meanwhile, the paper has proposed an improved particle swarm algorithm for optimization of fuzzy neural network based on new development in automation and intelligent technology and has carried out a positive analysis by using it. The new model in the convergence speed, adaptive value and diagnostic error, etc. is the optimal by comparing with BP neural network and PSO neural network. It can improve the subjective shortcoming of traditional methods that the staff in the field operation analyses data through the real-time monitoring system and the air drilling experts identify some characteristics of air drilling accident causes to reduce errors, improve the accuracy of diagnostics and become more intelligent.

Keywords Air and gas drilling · Fault diagnosis · PSO algorithm · Fuzzy neural network

22.1 Introduction

22.1.1 Research Background

In recent years, gas drilling is rapidly developed as a kind of new drilling technology, and it's the under-balanced drilling technology with the gas which is the main

D. Zhang · T. Zhu (✉) · Y. Lv · J. Hou · Y. He
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: judy_zhu-tingting@foxmail.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_22

circulatory mediator. Compared with the conventional drilling fluid drilling, gas drilling can significantly improve the mechanical drilling rate, shorten drilling cycle, reduce cost, reduce the damage to reservoir, find and protect hydrocarbon reservoir, improve recovery efficiency of oil and gas, and avoid abnormal condition under the shaft [3, 11, 17]. So far gas drilling has been widely used in Sichuan, Xinjiang, Changqing and many other areas. At the same time, as a new technology of drilling, air drilling also has many restricting factors [4, 6, 16], such as formation water, the downhole bums and abnormal drilling tool. Once these accidents appear, it will cause great economic losses to the enterprise. In order to analysis and processing air drilling accidents better and avoid the development of these accidents, it's necessary to monitor space drilling and early warning for the accident, therefore, the early warning system of air drilling accident monitoring is developed.

22.1.2 Research Status

At present, the research of air drilling fault diagnosis at home and abroad is judged mainly from the real time monitoring data and the characteristic of malfunction in the air drilling failure. McGuire [12] invented a mud separator monitoring system using the obtained data during drilling operations to calculate the volume of gas retained in the drilling fluid, the hydrostatic head of the drilling fluid and gas pressure in the separator on a continuing basis and informing field personnel of conditions in the mud separator indicating potential hazard. Jan [1] introduced a new drilling control and monitoring system, DrillView, which is a modular system that can be used on any size drilling unit, from a single portable top drive to a complete drilling unit with automated pipe handling, cement system, mud system and third party equipment. Xu [23] proposed an intelligent decision analysis system of drilling complex circs and accident based on network. Xu [25] implemented an intelligent diagnosis and processing system for drilling accidents. This system, which collected all kinds of accidents' cases occurred in oil fields and made full use of all types of information as well as experts' experience and knowledge, has self-learning function and can realize the diagnosis and processing for all kinds of drilling accidents. Bie [2] grasped the reason of the drilling tool malfunction through the analysis of working principle and working conditions of the drilling pump. Willersrud et al. [21] showed how estimated friction parameters and flow rates can be used to detect and isolate the type of incident, as well as isolating the position of a defect. Dashevskiy [5] tested that there is good agreement between the dynamic behavior of the BHA predicted by the NN model and the actual measured BHA response. Rajakarunakaran [14] presented the development of artificial neural network-based model for the fault detection of centrifugal pumping system. Meanwhile, Rumelhart [15] generalized error back propagation algorithm (BP), BP network has good ability of pattern classification and it's a good way to close to mine hoist parts operation parameters to hoist fault types of mapping, especially suitable for multi-mode system diagnosis of internal fault of mine hoist occurrence and development process. Once used in the diagnosis of complex failing system it can solve the bottleneck problem that the acquisition for conventional fault diagnosis expert system knowledge efficiently. Through the air drilling field research, and aimed at the insufficient in air drilling accident diagnosis, and based on the development of automatic and intelligent technology, this paper proposes the fuzzy neural network of accident diagnostic model that based on improved particle swarm algorithm, and so as to reduce the error, improve accuracy and get more intelligent effect.

22.2 Air Drilling Principle and the Cause of the Accident

22.2.1 The Working Principle of Air Drilling

The air drilling principle is to use gaseousness fluid as circulatory mediator instead of mud liquid, with air as working objects, and use air compressor to pressurize air initially, and then infiltrate into the borehole through the booster pressurization, so as to finish the work of carrying cuttings. Air drilling technology can increase oil productivity and eliminate the waste caused by a large number of leakages. For the formation that is high permeability, fractured and highly sensitive to the invasive liquid, air drilling technology is an effective way to reduce the invasion of fluid filtrate and solid and prevent damage to the reservoir. Meanwhile the air drilling technology can greatly improve the drilling speed, shorten the drilling cycle, reduce the cost and the reservoir damage, and it is beneficial to discover and protect the reservoir, avoid abnormal situation like well leakage and water sensitive strata collapse caused by the complicated structure of the formation.

22.2.2 The Cause of Air Drilling Accident

The cause of air drilling accident is a complicated problem, through the communication with experts and first-line operators, it preliminarily determines the main abnormal events, and statistic analyze the parameters of the abnormal events, and preliminary established air drilling engineering abnormal diagnosis, shown in Table 22.1.

22.3 Study Design

22.3.1 Particle Swarm Optimization

Particle Swarm Optimization (PSO) [20] was proposed by America social psychologists James Kennedy and electrical engineer Russel Eberhart in 1995. The basic idea originated in their early research, modeling and simulation result of how birds acted

Table 22.1 The diagnosis basis of air drilling abnormal events

Num	Accident types	Weigh	Torque	Force	Total hydrocarbon	Methane	Oxygen	CO	CO_2	Temperature	Humidity
1	Empty	↑↑	↓↓	–	–	–	–	–	–	–	–
2	Drill sting	–	–	↓	–	–	–	–	–	–	–
3	Drill tool broken	↓	↓↓	↓	–	–	–	–	–	–	–
4	Tical	↑↑	↑	–	–	–	–	–	–	–	–
5	Blocked	↓	↑	–	–	–	–	–	–	–	–
6	Air logging abnormal	–	–	–	↑	↑	–	–	–	–	–
7	Down hole bums	–	–	–	↓	↓	↓	↑	↑	↑	
8	Formation water	–	↑	↑	–	–	–	–	–	–	↑

Note the up arrow represents increased and the down arrow represents less in groups. One bird flying away from the flock to new habitat will lead to other birds flying to the new habitat because of the birds using simple rules to determine their own direction and speed. And once the first bird found the habitat and landed, the other birds will land one by one, finally all the birds landing. Eberhar and Kennedy amended the flock model to simulate the process of foraging, assuming that every bird learns from the birds with the best position around it, no collision between them which means the social and individual balance, so that every bird can find food. Then they put forward the thought of particle swarm optimization (PSO) together in 1995. PSO is a new evolutionary computation technique based on swarm intelligence. The swarm intelligence produced by individual cooperation and competition in the group can direct and optimize the search. POS has faster convergence speed, less parameters to adjust and stronger versatility. It is easy to realize, so as soon as raised it became a hotspot in the field of intelligent optimization and evolutionary algorithm, and has made great progress and wide application. At present, it's widely used in the objective function optimization, the fuzzy control system, neural network training and many other fields. The basic idea of PSO is all the possibility of each optimization solution are particles in the search space. Every particle has a fitness value decided by optimizing function and a velocity vector which decides the direction and distance of flight, afterwards all the particles search in the possible solution space according to the current optimum particles. The initial state of PSO is a group of random particles, and then it find the optimal solution by iteration. During each iteration, every particle tracks two extreme value to renew. The first extremum is the best key of the particle recently, the second extremum is the optimal solution the whole particle swarms so far, respectively the individual optimal solution and the group optimal solution. Supposing in a D-dimensional space, there are M particles to search. Then we use $x_i = (x_{i1}, x_{i2}, \ldots, x_{id})$ to remark the position of particle i, $i = 1, 2, \ldots, M$. The speed of the particle is a D-dimensional vector too, remarked as $v_i = (v_{i1}, v_{i2}, \ldots, v_{id})$. So far the optimal location for the particle i is $x_i = (x_{i1}, x_{i2}, \ldots, x_{id})$, $i = 1, 2, \ldots, M$, and the optimal location for the particle swarm is $p_g = (p_{g1}, p_{g2}, \ldots, p_{gd})$. Therefore the updated formulas of individual particle show as follows:

$$v_{id}(t+1) = v_{id}(t) + c_1 r_1 (p_{id} - x_{id}(t)) + c_2 r_2 (p_{gd} - x_{id}(t)), \tag{22.1}$$

$$x_{id}(t+1) = x_{id}(t) + v_{id}(t+1). \tag{22.2}$$

When $v_{id} > V\max$, $v_{id} = V\max$; when $v_{id} < V\max$, $v_{id} = V\min$, $i = 1, 2, \ldots, M$, $d = 1, 2, \ldots$. Acceleration constants c_1 and c_2 are nonnegative constants. Random numbers r_1 and r_2 obey uniform distribution on [0, 1]. These are present position of particle $i\,x_{id}$, the precious best location searched so far p_{id}. p_{gd} is the best position currently searched of the whole particle swarm. v_{id} is the present speed of the particle i. $v_{id} \in [V\min, V\max]$, $V\max$ is the biggest limited speed and $V\min$ is the minimum limited speed. The process of PSO is shown as Fig. 22.1.

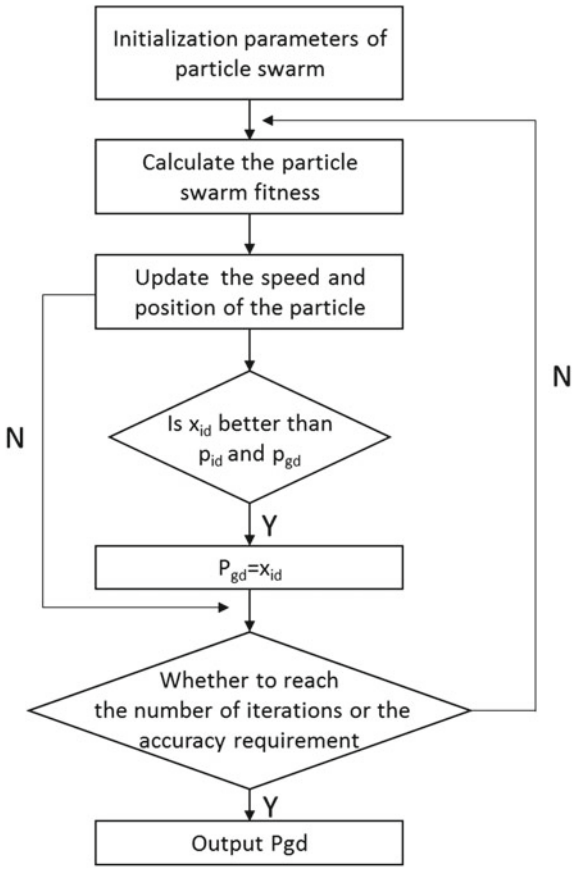


Fig. 22.1 The flow chart of POS

22.3.2 BP Neural Network Architecture

BP neural network is a forward neural network without feedback. It is composed of input layer, hidden layer and output layer. BP neural networks algorithm is also known as the error back propagation algorithm. The learning process of this algorithm is divided into two parts, the forward propagation and the backward propagation. The forward process computes the output from nodes in each layer basing on the propagation process of the input vector from the input layer to the hidden layer then to the output layer. The back process is based on the error between the output value and the ideal results of the output node to modify the weight matrix V and W from the output layer to the input layer then to the hidden layer. Two processes repeatedly alternating until convergence. Assuming that the BP neural network has N nodes per layer, the function is a nonlinear Sigmoid function that generally is $F(x) = 1/(1 + e - x)$, and the learning set includes a M sample mode $\left(X_p, Y_p\right)$.

To learning samples P $(P = 1, 2, M, J)$ the input of node j is labeled as net_{pi}, the output labeled as O_{pj}. Then:

$$O_{pj} = f(\text{net}_{pi}). \tag{22.3}$$

If the initial weights of the network are arbitrary, the error between the output and the desired results (d_{pj}) for each input sample P is:

$$E = \sum E_p = (\sum (d_{pj} - O_{pj})^2)/2. \tag{22.4}$$

The weight modified formula for BP network is:

$$W_{ji} = W_{ji}(t) + \eta \delta_{pj} O_{pj}. \tag{22.5}$$

$$\delta p\text{j} = \left[\begin{array}{ll} f(\text{net})(dpj - Opj), & \text{for the output node,} \\ f(\text{net}) \sum_k \delta pj Wkj, & \text{for the input node.} \end{array} \right.$$

The introduction of learning rate η is to speed up the convergence rate of the network. The common weight correction formula also need to add an inertial coefficient, so as to:

$$W_{ji} = W_{ji}(t) + \eta \delta_{pj} O_{pj} + \alpha (W_{ji}(t) - W_{ji}(t-1)). \tag{22.6}$$

In the formula, α is a constant determining the influence of the last weight on the weight value [7].

22.3.3 A Fuzzy Neural Network Based on Improved Particle Swarm Optimization

Air drilling accident is a complex and multiple factors of the system. Each kind of accident and logging parameter data is a nonlinear relationship, so the simple algorithm to predict air drilling accident, and it's not effect. Because BP neural network has the good effect to the nonlinear, so it uses the BP neural network diagnosis model. But neural network also has some shortcomings, are slow training speed, easy to fall into local optimum and result in great error in the accident diagnosis, this article uses the improved PSO algorithm for training, so as to improve the training speed. Meanwhile, this paper mixes the neural network and fuzzy system together, and gives play to the complementarity of the two. Neural network and fuzzy system are belonging to no model estimator and a nonlinear dynamic system, and it's out of uncertainty, nonlinear and other powerful tool for uncertainty problem. The knowledge extraction and expression of fuzzy system is more convenient, it's used to express the uncertain and fuzzy knowledge, but its lack of self-learning and adaptive ability, which is the advantage of neural network. So, appropriately combined fuzzy logic and neural network, and it will be better than single neural network or fuzzy system that absorbs the merits of the two.

Fuzzy neural network is a new network that combined artificial neural network and fuzzy reasoning. Applying it to the fault diagnosis system, the system not only has the advantages of nonlinear, robust, adaptive and self-learning, but also has the advantages of fuzzy programming and fuzzy reasoning. BP algorithm is easy to fall into local optimum and over fitting phenomenon, at the same time, it's long time for large and complicated system to calculate. So we use the PSO algorithm to optimize the fuzzy neural network, so as to improve the diagnostic ability of network training speed and network. Combined with the actual situation of air drilling system, we use the fuzzy neural network based on Takagi–Sugeno model [8–10, 13, 19, 22]. According to the fuzzy inference characteristics of Takagi–Sugeno model, it's combined with neural network, and constructs neural fuzzy system with adaptive learning ability. The fuzzy neural network structure based on Takagi–Sugeno model is as shown in Fig. 22.2.

From Fig. 22.2, it shows that the network has antecedent network and consequent network, the antecedent network is used to match the antecedent of fuzzy rule, and

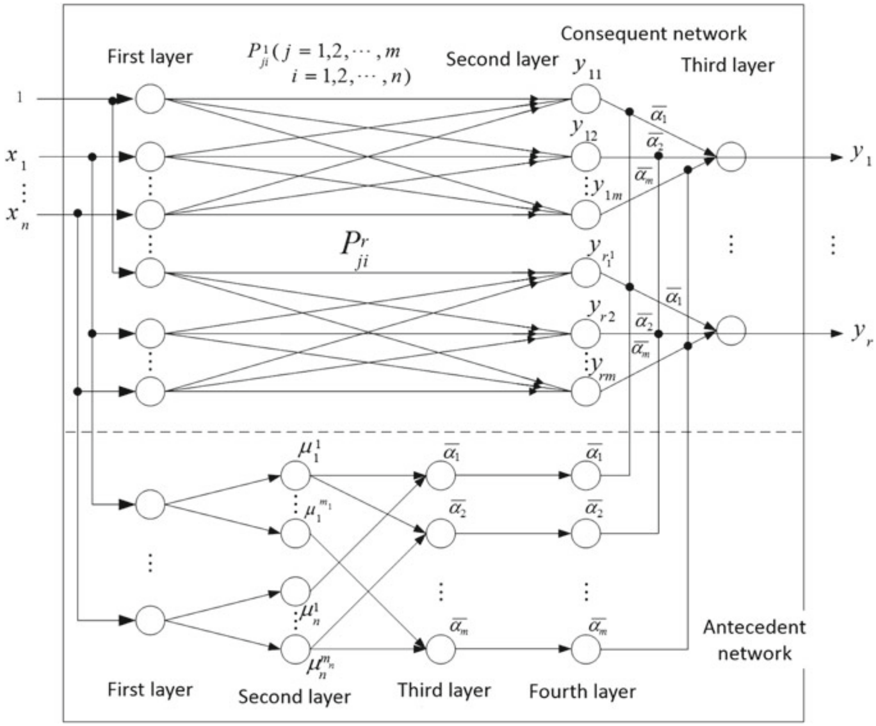


Fig. 22.2 The fuzzy neural network structure based on Takagi–Sugeno model

consequent network is used to match the consequent of fuzzy rule. The antecedent is composed of 4 layers: the first layer is input layer, the second layer is that each node represents a variable value of voice, the third layer is that each node represents a fuzzy rule, the fourth layer is the same as the third, it realized four normalized calculation process. The consequent network consists of r paratactic sub-networks that are the same structure, and each network produces an output. The first layer of sub-network is input layer, and it delivers the input variables to the second layer. The second layer has m nodes, each node represents a rule. And the third layer is the output of the computing system.

About the network learning algorithm, the paper uses the dynamic acceleration constant of particle swarm optimization algorithm to optimize the weights. The parameters that should be adjusted in the fuzzy neural network are: the connection weights of consequent network, the center and width of membership function in the second node of antecedent network. The fuzzy neural network frame that based on improved particle swarm algorithm is as shown in Fig. 22.3.

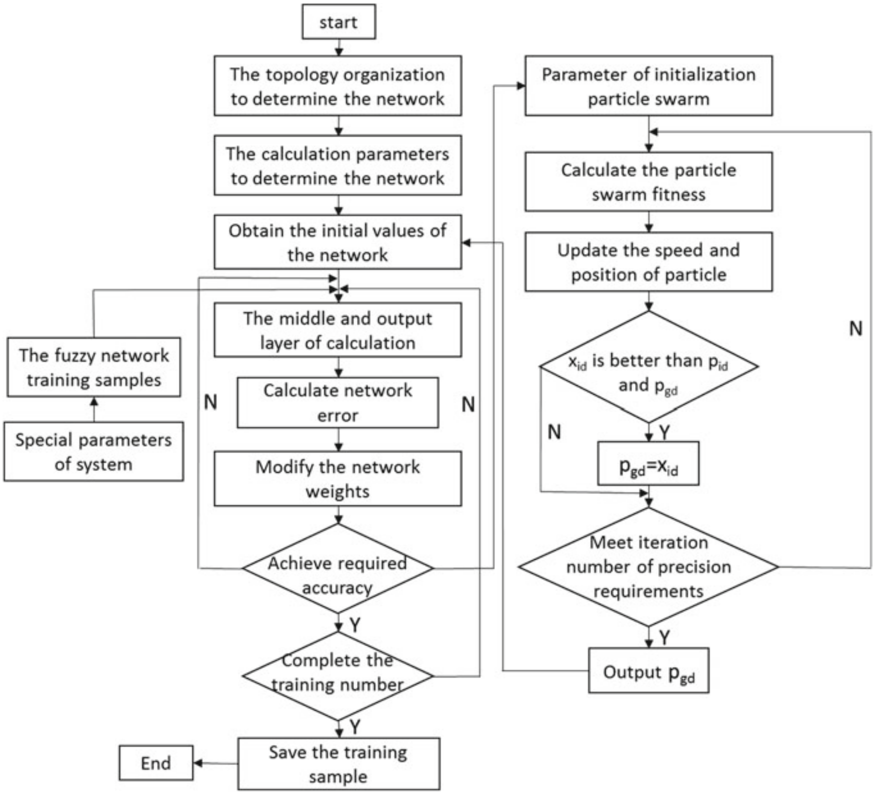


Fig. 22.3 The fuzzy neural network structure based on Takagi–Sugeno model

22.4 The Empirical Analysis

Air drilling accident diagnosis system is to analyze real-time monitoring data in the process of air drilling, and combined with the knowledge of experts for feature extraction, and matching with the practice, through the training of intelligent algorithm to establish a fuzzy neural network.

22.4.1 The Network Structure Design

Diagnosis system has eight kinds of accident that are: formation water, underground explosion, gas logging abnormal, emptying, thorn drilling tools, breaking drilling tools, cards and blocked. There are nine factors that affect accidents, they are: temperature, humidity, the concentration of carbon monoxide and the concentration of carbon dioxide, the concentration of oxygen, torque, hook load, pressure and total hydrocarbon (a compound containing Sand H). Due to the actual situation, in the design of neural network structure, the paper uses nine inputs and four outputs, nine inputs represent nine influence factors, and for eight accidents, the paper uses binary notation to represent the types of accidents, as the four point vectors of network target output vector. The details are shown in Table 22.2.

The choice of hidden layer neurons number is a relatively complex problem, generally it needs to determine according to the designer's experience and experiment many times. At present, experts and scholars study to determine the formula of hidden layer neurons are [18]:

(1) $n_1 = \log_2 n$, which n is the number of input neurons.
(2) $n_1 = \sqrt{n+m} + a$, which n is the number of input neurons, m is the number of output neurons, a general value for a is [4].
(3) $\sum_{i=0}^{n} C_{n_1}^{i} > k$, which k is the number of samples, n_1 is the number of hidden layer neurons, n is the number of input neurons.

The selection of the hidden layer neural network in paper: the number of hidden layer neurons is set to 19, but it's not certain, therefore, the network structure of fuzzy neural network is 9-q-4.

22.4.2 The Pretreatment of Data

Air drilling accident diagnosis system is a complex nonlinear system, and there are many factors that influence the stability, the paper selects the data according to index that provide from experts. The method to select data in paper is: every one minute to select one data, and to select the data of accident at the same time, so that it can

Table 22.2 The input/output index value of improved particle swarm fuzzy neural network

Accident	Input indicators	Basic value	Variable quantity	Weight	Desired output
Normal state	–	–	–	–	0000
Formation water	Humidity (%)	55	15	85	1000
	Pressure (Mpa)	5	2	10	
	Torque ($KN \cdot m$)	7.5	2	5	
Underground explosion	CO_2 (%)	0.02	0.05	60	1001
	O_2 (%)	23	3	30	
	CO (%)	0	0.05	10	
Gas logging abnormal	Total hydrocarbon (%)	0	1	70	1010
	C_1 (%)	0	1	30	
Emptying	Hook load ($K \cdot N$)	1150	150	60	1011
	Torque ($KN \cdot m$)	8	4	40	
Thorn drilling tools	Pressure (Mpa)	4.2	3	100	1100
Breaking drilling tools	Hook load ($K \cdot N$)	1150	150	65	1101
	Torque ($KN \cdot m$)	8	3	10	
	Pressure (Mpa)	4.2	3	25	
Cards	Hook load ($K \cdot N$)	1150	200	90	1110
	Torque ($KN \cdot m$)	8	3	5	
	Pressure (Mpa)	4.2	3	5	
Blocked	Hook load ($K \cdot N$)	1150	150	70	1111
	Torque ($K \cdot N$)	8	3	30	

guarantee eight accidents will be in data concentration that paper needs. The paper chooses 300 data, and it can be divided into two parts: 250 data are the training data, 50 data are the test set.

Before using the neural network to deal with system, it needs to get the data normalization processing. Meanwhile, after data collection, the units are not unified, so the first thing is to dimensionless processing. Normalization methods have many forms, this paper adopts is $\hat{x} = \frac{x - x_{\min}}{x_{\max} - x_{\min}}$, which x is the raw data, $x_{\min}$ is the minimum raw data and $x_{\max}$ is the maximum.

22.4.3 Experiment Design

The requirement of air drilling accident diagnosis system to the error of things diagnoses is very high. Therefore, in the experimental design, the paper needs to off line training and inspect result of improved particle swarm optimization algorithm, meanwhile, compared with the performance of other algorithms, and choose the optimal accident diagnosis method, and the specific algorithm of parameter design is shown in Table 22.3. The paper establishes the expert evaluation system of fuzzy theory, the training diagnosis system of BP network, improved PSO neural network training diagnostic system and improved PSO fuzzy neural network training diagnosis system to diagnose the air drilling accident. Finally, through the comparison shows the advantages of improved PSO fuzzy neural network training diagnosis system, so that in the system integration, it uses this algorithm to diagnose online real-time fault.

For the feed forward neural network, the performance test is carried out by using the function approximation problem and the classification problem. The research problem of paper is the classification problem, so it adopts the performance evaluation indicators are:

(1) the classification error rate of training set;
(2) the classification error rate of test set;
(3) the mean square error of training set;
(4) the mean square error of test set. For air drilling accident diagnosis system, the paper will evaluate each algorithm by minimal error risk.

22.4.4 The Result Analysis and Evaluation of Experiment

First the paper tests for the improved PSO algorithm, and tests its function effect, and compared with other optimization algorithm in average convergence rate, convergence algebra and average fitness value [24]. Meanwhile, this experiment for air drilling accident to design the more optimal neural network structure, and uses the improved particle swarm fuzzy neural network to train and get good result, as shown

Table 22.3 Different neural network parameter settings

Neural network structure	Algorithm	$T_{\max}$	$\omega_{\min}$	Number of particles	Constant				Accelerated constant (c_1, c_2)	Precision ξ	Number of maximum iterations $T_{\max}$
					R_1	R_2	R_3	R_4			
9-15-4	BP	–	–	–	–	–	–	–	–	0.001	1000
	PSO	–	–	30	–	–	–	–	2, 2	0.001	1000
	WCPSO	1.5	0.5	30	1	0.5	5	2	–	0.001	1000
9-17-4	BP	–	–	–	–	–	–	–	–	0.001	2000
	PSO	–	–	30	–	–	–	–	2, 2	0.001	2000
	WCPSO	1.5	0.5	30	1	0.5	5	2	–	0.001	2000

Table 22.4 The operation results of different algorithms of fuzzy neural network

Fuzzy neural network structure	Number of particles (m)	Dimension (n)	Convergence rate (%)(BP/PSO/WCPSO)			Average convergence algebra (BP/PSO/WCPSO)			Average fitness (BP/PSO/WCPSO)		
9-15-4	30	214	60	80	90	221	198	128	0.094	0.017	0.0091
9-17-4	30	242	70	90	100	276	252	143	0.083	0.0073	0.00041

Table 22.5 The test result of different structure of fuzzy neural network

Fuzzy neural network structure (WCPSO)	Number of particles (m)	Dimension (n)	Diagnosis error rate of training set (%)	Diagnosis error rate of test set (%)
9-15-4	30	214	0	4
9-17-4	30	242	0	0

in Tables 22.4 and 22.5. Improved particle swarm fuzzy neural network is based on data modeling method in which the fuzzy membership function and fuzzy rule is trained by a lot of data, but no longer based on experience and intuition. Therefore, the improved PSO fuzzy neural network training expert diagnostic system is applied to situation that some characteristics such as air drilling system are not completely understood by the public.

From Tables 22.4 and 22.5, the performance of WCPSO algorithm is better than BP algorithm and PSO algorithm, the convergence rate and fitness value are relatively small, and meanwhile, the structure of 9-17-4 fuzzy neural network is better than the structure of 9-15-4. At the same time, the paper also uses the knowledge rules of experts to establish the single fuzzy inference system, but the proving result is not ideal, because the knowledge of experts is not complete. So in the air drilling accident diagnosis system, the paper uses the improved particle swarm accident diagnosis fuzzy neural network, the optimized algorithm is WCPSO, and the structure of fuzzy neural network is 9-17-4.

22.5 Conclusion

The accident diagnosis of air drilling is important for the drilling sector of oil companies, the paper concludes and summarizes the method of air drilling accident at home and abroad and puts forward the shortcomings. For the development trend of accident diagnosis method, and combined with the working principle of air drilling, it proposes the diagnostic scheme that based on the improved particle swarm algorithm to optimize neural network. Paper analyzes the short of the BP neural network and particle swarm optimization, and introduces an improved particle swarm optimization into the BP neural network, and introduces the fuzzy theory into this algorithm. Paper applies the improved particle swarm fuzzy neural network into air drilling accident diagnosis system, through the empirical analysis on the MATLAB platform, the result shows that the improved particle swarm fuzzy neural network meets the requirements in the air drilling diagnosis system.

The research innovations of paper are: Firstly, the intelligent fault diagnosis method conformed to the development trend of accident diagnosis is proposed. Using the sensor technology, the parameters of the air drilling process can be real-time monitored, and the use of computer technology can visual so that we can optimize the neural network to improve the speed of fault diagnosis. Then, a large number of knowledge about the intelligent optimization algorithm is mentioned. The advantages and disadvantages of these algorithms are complementary so that a fuzzy neural network algorithm based on improved particle swarm optimization is proposed. At the same time, considering the feasibility and portability, the algorithm is tested by MATLAB software and packaged by MATLAB Builder. Essay Uses $C\sharp$ to call the .NET components, thus the system can implement the calling to the components based on the improved particle swarm algorithm in. NET environment through the

C♯ programming, making the air drilling accident diagnosis system coming to work and playing a positive role in the monitoring and fault diagnosis of air drilling process.

Air drilling technology is a newly emerging technology in recent years, and the prospects of paper are:

(1) The cause of accident and the mechanism have yet to be analyzed through practice and data analysis, so as to improve the mechanism of air drilling fault diagnosis system, and improve the diagnostic accuracy of fault.
(2) The future work can be established on a dynamic real-time online diagnosis system.
(3) The intelligent fault diagnosis is a trend of fault diagnosis, and the research and application of the intelligent algorithm are the direction of future work.

References

1. Artymiuk J, Sokalski M (2004) The new drilling control and monitoring system. Acta Montanistica Slovaca 3:145–151
2. Bie FF, Pei JF, Lv FX (2014) Research on fault diagnosis method for crankshaft of drilling pump based on operational deflection analysis. Adv Mater Res, Trans Tech Publ 989:2899–2903
3. Chen G, Chen X et al (2006) The application of air and air/foam drilling technology in tabnak gas field, Southern Iran. In: IADC/SPE Asia Pacific drilling technology conference and exhibition, vol 2006, no 11. Society of Petroleum Engineers, Dallas, pp 13–15
4. Cooper LW, Hook RA, Payne BR (1997) Investigation of explosion occurrence in underbalanced drilling. In: deep drilling and production symposium of petroleum engineer of AIME. Society of Petroleum Engineers, Dallas, pp 17–19
5. Dashevskiy D, Dubinsky V et al (1999) Application of neural networks for predictive control in drilling dynamics. In: SPE annual technical conference and exhibition. Society of Petroleum Engineers, Dallas
6. Guo B, Ghalambor A (2002) Gas volume requirements for underbalanced drilling: deviated holes. PennWell Books, Tulsa
7. Kennedy J, Eberhart RC (1995) Particle swarm optimization. In: IEEE International Conference on Neural Networks, vol IV. IEEE Service Center, Piscataway, pp 1942–1948
8. Kukolj D, Kulic F, Levi E (2000) Design of the speed controller for sensorless electric drives based on AI techniques: a comparative study. Artif Intell Eng 14(2):165–174
9. Leng G, McGinnity TM, Prasad G (2005) An approach for on-line extraction of fuzzy rules using a self-organising fuzzy neural network. Fuzzy Sets Syst 150(2):211–243
10. Li XF, Xu JP et al (2004) The establishment of self-adapting algorithm of BP neural network and its application. Syst Eng-Theory Pract 5:001
11. Lyons WC, Guo B et al (2009) Air and gas drilling manual: applications for oil and gas recovery wells and geothermal fluids recovery wells. Gulf Professional Publishing, Houston
12. McGuire LL, McGuire W, Brych F (2000) Mud separator monitoring system. US Patent 6,105,689
13. Ponce-Cruz P, Ramírez-Figueroa DF (2010) Neuro-fuzzy controller theory and application. Intelligent Control Systems with LabVIEW, pp 89–122
14. Rajakarunakaran S, Venkumar P et al (2008) Artificial neural network approach for fault detection in rotary system. Appl Soft Comput 8(1):740–748
15. Rumelhart DE, Mcclelland JL (1987) The PDP research group. The MIT Press, Massachusetts
16. Shahbazi K, Mehta SA et al (2007) Investigation of explosion occurrence in underbalanced drilling. In: Production and operations symposium. Society of Petroleum Engineers

17. Su YN, Huang HC et al (2009) Oil gas drilling technology in China: past and present. China Oil Gas 16(4):36–40
18. Tang X, Qiu G et al (2007) A clustering algorithm based on particle swarm optimization and self-organizing map. J-Huazhong Univ Sci Technol Nat Sci Ed 35(5):31
19. Venkatasubramanian V, Chan K (1989) A neural network methodology for process fault diagnosis. AIChE J 35(12):1993–2002
20. Wei X, Pan H (2010) particle swarm optimization and intelligent fault diagnosis. National Defence Industry Press, Beijing (In Chinese)
21. Willersrud A, Blanke M et al (2015) Fault diagnosis of downhole drilling incidents using adaptive observers and statistical change detection. J Process Control 30:90–103
22. Wu S, Er MJ (2000) Dynamic fuzzy neural networks-a novel approach to function approximation. IEEE Trans Syst, Man, Cybern, Part B: Cybern 30(2):358–364
23. Guo XR, Xu XZ (2011) Research on intelligent decision analysis system of drilling complex circs and accident based on network. In: 3rd World Congress in Applied Computing, Computer Science, and Computer Engineering, pp 815–831
24. Yang G, Tang X (1998) Evaluation method of the quality of forecast model. China Soft Sci 11:86
25. Xu XZ, Guo XR (2014) Research on intelligent diagnosis and processing system for drilling accident. In: Fifth international conference on intelligent systems design and engineering applications (ISDEA), 2014. IEEE, New York, pp 817–820

Chapter 23
On General Form of Tanh Method and Its Application to Medical Problems

Hamidoğlu Ali

Abstract The tanh method is used to compute travelling waves solutions of one-dimensional non-linear wave and evolution equations. The technique is based on seeking travelling wave solutions in the form of a finite series in tanh. However, the mentioned method is not always *efficient* method to solve some types of one dimensional non-linear partial differential equations in more general sense. In this article, we construct new general transformation of tanh function which is more *effective* in the sense of getting general solutions. By using our new transformation, we solved some important non-linear partial differential equations related with medicine, biology and physics. We examine Belousov–Habotinskii reaction which is often used to understand embryonic development and some of the complex wave behavior in the heart and other organs in the body, Fitzhugh–Nagumo equation which arises in population genetics and models the transmission of nerve impulses, and some other crucial non-linear partial differential equations applied in physics.

Keywords Belousov–Habotinskii reaction · Nonlinear PDEs · Exact solutions · Nonlinear waves · Tanh method

23.1 Introduction

Nonlinear partial differential equations are encountered in various fields of mathematics, medicine, chemistry, and mathematical biology (population dynamics [12]), physics (fluid dynamics [15]), and numerous applications. Exact (closed-form) solutions of differential equations play a crucial role in the proper understanding of qualitative features of many phenomena and processes in various areas of natural science. Because of the increasing interest in finding exact solutions for those problems, many powerful methods have been developed, such as, tanh-function method [4, 8–11], inverse scattering method [1] and direct algebraic method [3, 5, 6].

H. Ali (✉)
Department of Mathematics, Middle East Technical University, 68400 Ankara, Turkey
e-mail: ali.hamidoglu@metu.edu.tr

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_23

In this paper, we introduce a similar technique to [4] using new transformation which is the general form of tanh function to obtain exact solutions for nonlinear partial differential equations (PDEs). The first step is to use an independent variable in order to turn the nonlinear PDEs into other nonlinear ordinary differential equations (ODEs). After that, we introduce a new independent variable in terms of our new transformation and the solution(s) we are looking for would be written as a finite power series in terms of our new variable. We briefly discuss the tanh method, which was pioneered by Malfliet [8]. We investigate the nonlinear wave and evolution equations (in one dimensional) are written as

$$A(u, u_t, u_x, u_{xx}, \cdots) = 0 \quad \text{or} \quad A(u, u_{tt}, u_x, u_{xx}, \cdots) = 0. \tag{23.1}$$

We assume that these equations admit exact travelling wave solutions. The first step is to construct a new variable ξ in terms of our independent variables, x and t, $\xi = k(x - Vt)$, which is the travelling frame of reference. Here, k and V represent the wave number and velocity of the travelling wave respectively. Accordingly, the quantity $u(x, t)$ is replaced by $U(\xi)$, so that we deal with ODEs rather than with PDEs. Therefore, the Eq. (23.1) are transformed into

$$-kV\frac{dU}{d\xi} = A\left(U, k\frac{dU}{d\xi}, k^2\frac{d^2U}{d\xi^2}\right), \tag{23.2}$$

or

$$k^2V^2\frac{d^2U}{d\xi^2} = A\left(U, k\frac{dU}{d\xi}, k^2\frac{d^2U}{d\xi^2}\right). \tag{23.3}$$

Next step, we introduce new independent variable in terms of ξ,

$$Y = \frac{e^{\xi} + \eta e^{\eta\xi}}{e^{\xi} + e^{\eta\xi}}, \qquad \text{where } \eta \in \mathbb{R},$$

which is the general form of tanh transformation. The coefficients of the *ODE* in $U(\xi) = F(Y)$ then only depends on Y. Also, observe that

$$\frac{d}{d\xi} = (-Y^2 + (\eta + 1)Y - \eta)\frac{d}{dY}.$$

Therefore, it makes sense to attempt to find solution(s) as a finite power series in Y,

$$F(Y) = \sum_{n=0}^{N} a_n Y^n, \tag{23.4}$$

which incorporates solitary-wave and shock-wave profiles. We determine the degree (N) of the power series by using the balancing procedure.

23.2 Belousov–Habotinskii Reaction

In this section, we consider the following model of Belousov–Habotinskii reaction which is often appeared in medicine (see [2, 12]).

$$\begin{cases} u_t = u(1-u-rv) + u_{xx}, \\ v_t = -auv + v_{xx}, \end{cases} \tag{23.5}$$

where $a \neq 1$ and r are positive parameters. In this problem, we look for waves under following boundary conditions

$$u(-\infty, t) = 0, \qquad v(-\infty, t) = 1, \qquad u(+\infty, t) = 1, \qquad u(+\infty, t) = 0. \tag{23.6}$$

Before looking for travelling wave solutions we should note that there are some special cases which reduce the problem to a Fisher–Kolmogorov equation by setting the following transformation

$$v = \frac{1-a}{r}(1-u). \tag{23.7}$$

Using Eq. (23.7) in Eq. (23.5), the system reduces to

$$\frac{\partial u}{\partial t} = au(1-u) + \frac{\partial^2 u}{\partial x^2}, \tag{23.8}$$

which is Fisher–Kolmogorov equation. To obtain the exact solution, we introduce

$$Y = \frac{e^{\xi} + \eta e^{\eta\xi}}{e^{\xi} + e^{\eta\xi}},$$

where $\xi = k(x - Vt)$ and $\eta \in \mathbb{R}$. For this problem, we should assume that $k \in (-\frac{\sqrt{a}}{\sqrt{6}}, 0)$ and $\eta < 0$. Now, using our transformation, we get the system in terms of Y,

$$\begin{aligned} &kV(-Y^2 + (\eta+1)Y - \eta)\frac{dF(Y)}{dY} + aF(Y)(1 - F(Y)) \\ &+ k^2(-Y^2 + (\eta+1)Y - \eta)\Big[\frac{d}{dY}\Big[(-Y^2 + (\eta+1)Y - \eta)\frac{dF(Y)}{dY}\Big]\Big] = 0. \end{aligned} \tag{23.9}$$

After balancing the highest power of Y, we get $2N = N + 2$, i.e., $N = 2$. Here, in this problem, we search our solution as $F(Y) = b_0(1-Y)^2$ (see e.g., [4]). After some algebra, we have the following

$$
\begin{aligned}
&Y^4(6b_0k^2 - ab_0^2) + Y^3(-2b_0kV - 10b_0k^2\eta - 14b_0k^2 + 4ab_0^2)\\
&+ Y^2(2b_0kV\eta + 4b_0kV + 4b_0k^2\eta^2 + 22b_0k^2\eta + 10b_0k^2 - 6ab_0^2 + ab_0)\\
&+ Y(-8b_0k^2\eta^2 - 14b_0k^2\eta - 2b_0k^2 + 4ab_0^2 - 2ab_0 - 4b_0kV\eta - 2b_0kV)\\
&+ (2b_0kV\eta + 4b_0k^2\eta^2 + 2b_0k^2\eta - ab_0^2 + ab_0) = 0. \qquad (23.10)
\end{aligned}
$$

The equality Eq. (23.10) holds if and only if each coefficient of powers of Y vanishes. After some computations, we have the following

$$
\eta = 1 + \frac{\sqrt{6a}}{6k}, \qquad V = -\frac{5\sqrt{a}}{\sqrt{6}}, \qquad b_0 = \frac{6k^2}{a}, \qquad k \neq 0. \qquad (23.11)
$$

Now, observe that $x \to -\infty$ means $Y \to 1$, i.e., $F(Y) \to 0$, namely, $u(-\infty, t) = 0$. Hence, first boundary condition satisfies. For the second one, if $x \to +\infty$, then $Y \to \eta$ which implies $F(Y) \to b_0(1-\eta)^2$. However, from Eq. (23.11) we have $b_0(1-\eta)^2 = 1$, i.e., $u(+\infty, t) = 1$. Hence, the last boundary condition satisfies.

In the end, we have the following solution for Belousov–Habotinskii reaction under the boundary conditions Eq. (23.6):

$$
u(x,t) = \frac{6k^2}{a}\left\{1 - \frac{e^{k(x+\frac{5\sqrt{a}}{\sqrt{6}}t)} + (1+\frac{\sqrt{6a}}{6k})e^{(1+\frac{\sqrt{6a}}{6k})(x+\frac{5\sqrt{a}}{\sqrt{6}}t)k}}{e^{k(x+\frac{5\sqrt{a}}{\sqrt{6}}t)} + e^{(1+\frac{\sqrt{6a}}{6k})(x+\frac{5\sqrt{a}}{\sqrt{6}}t)k}}\right\}^2.
$$

23.3 The Fitzhugh–Nagumo Equation

Here, we consider the following form of partial differential equations which is applied to population genetics (see, e.g., [2, 12, 13]).

$$
\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2} - u(1-u)(a-u). \qquad (23.12)
$$

In this problem, we assume that $a^2 - a + 1 \neq 0$. We firstly convert the PDE Eq. (23.12) into ODE, by the same method

$$
-kV\frac{dU(\xi)}{d\xi} = k^2\frac{d^2U(\xi)}{d\xi^2} - U(\xi)(1-U(\xi))(a-U(\xi)). \qquad (23.13)
$$

Now, using our transformation, we get the following

$$kV(-Y^2+(\eta+1)Y-\eta)\frac{dF(Y)}{dY}-F(Y)(1-F(Y))(a-F(Y))$$
$$+k^2(-Y^2+(\eta+1)Y-\eta)\Big[\frac{d}{dY}\Big[(-Y^2+(\eta+1)Y-\eta)\frac{dF(Y)}{dY}\Big]\Big]=0. \quad (23.14)$$

Balancing the highest powers of Y, we have $N+2=3N$, or $N=1$.

Hence, we obtain $F(Y)=s_0+s_1Y$. After putting $F(Y)$ into Eq. (23.14), we have the following

$$Y^3(-s_1^3+2k^2s_1)+Y^2(-3k^2s_1(\eta+1)+s_1^2(a+1)-3s_1^2s_0-kVs_1)$$
$$+Y(k^2s_1(\eta^2+1)+4k^2\eta s_1+2s_1s_0(a+1)-as_1-3s_1s_0^2+kV(\eta+1)s_1)$$
$$+(-k^2s_1\eta(\eta+1)+s_0^2(a+1)-s_0^3-as_0-kV\eta s_1)=0. \quad (23.15)$$

The equality Eq. (23.15) holds when each coefficient of power of Y vanishes. Hence, from the first coefficient, we obtain that $s_1^2=2k^2$ and for $\eta\neq-1$ (we consider the case in which $\eta=-1$ later), we get $V=-3k(\eta+1)$ and $s_0=(a+1)/3$ from second coefficient. By using these values, we obtain the following equality from the third coefficient

$$\frac{a^2-a+1}{6}=k^2(\eta^2+\eta+1). \quad (23.16)$$

From the last coefficient, we have

$$\frac{(a-2)(2a-1)(a+1)}{54k^2}=-s_1\eta(\eta+1). \quad (23.17)$$

We further assume that $a-2\neq0,\quad 2a-1\neq0$ and $a+1\neq0$ to make the left hand side of Eq. (23.17) to be non-zero. From Eqs. (23.16) and (23.17) together, we obtain the following cases:

Case 1. $\eta=\dfrac{1-2a}{a-2},\quad k=\pm\dfrac{(a-2)}{3\sqrt{2}},\quad s_1=\dfrac{2-a}{3}.$

Case 2. $\eta=\dfrac{a+1}{a-2},\quad k=\pm\dfrac{(a-2)}{3\sqrt{2}},\quad s_1=\dfrac{2-a}{3}.$

Case 3. $\eta=\dfrac{1-2a}{a+1},\quad k=\pm\dfrac{(a+1)}{3\sqrt{2}},\quad s_1=-\dfrac{a+1}{3}.$

Case 4. $\eta=\dfrac{a-2}{a+1},\quad k=\pm\dfrac{(a+1)}{3\sqrt{2}},\quad s_1=-\dfrac{a+1}{3}.$

Case 5. $\eta=\dfrac{a+1}{1-2a},\quad k=\pm\dfrac{(2a-1)}{3\sqrt{2}},\quad s_1=\dfrac{2a-1}{3}.$

Case 6. $\eta=\dfrac{a-2}{1-2a},\quad k=\pm\dfrac{(2a-1)}{3\sqrt{2}},\quad s_1=\dfrac{2a-1}{3}.$

Hence, from each case we obtain the solution of Eq. (23.12). Now let us consider the case $\eta = -1$, which is the case that our new model turns out to be tanh transformation. More precisely, if $\eta = -1$ in the Eq. (23.15), then after some computations, we get the following cases:

Case 1. $s_0 = \frac{1}{2}, \quad s_1 = \frac{1}{2}, \quad k = \pm\frac{\sqrt{2}}{4}, \quad V = \pm\frac{2a-1}{\sqrt{2}}.$

Case 2. $s_0 = \frac{a}{2}, \quad s_1 = \frac{a}{2}, \quad k = \pm\frac{\sqrt{2}a}{4}, \quad V = \pm\frac{a(2-a)}{\sqrt{2}}.$

Case 3. $s_0 = \frac{1}{2}(a+1), \quad s_1 = \frac{1}{2}(1-a), \quad k = \pm\frac{\sqrt{2}}{4}(1-a), \quad V = \pm\frac{a^2-1}{\sqrt{2}}.$

23.4 The Burgers Equation

The Burgers equations,

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} - a\frac{\partial^2 u}{\partial x^2} = 0, \tag{23.18}$$

is one of the most crucial nonlinear diffusion equations which is used for describing wave processes in gas dynamics, hydrodynamics, and acoustics (see, e.g., [4, 10]). The positive parameter a is a dissipative effect. Here, we firstly transform Burgers Eq. (23.18) into

$$-kV\frac{dU}{d\xi} + kU\frac{dU}{d\xi} - ak^2\frac{d^2U}{d\xi^2} = 0. \tag{23.19}$$

Next, we introduce

$$Y = \frac{e^{\xi} + \eta e^{\eta\xi}}{e^{\xi} + e^{\eta\xi}}, \quad \eta \in \mathbb{R}, \tag{23.20}$$

which yields

$$\begin{aligned} &- kV(-Y^2 + (\eta+1)Y - \eta)\frac{dF(Y)}{dY} + kF(Y)(-Y^2 + (\eta+1)Y - \eta)\frac{dF(Y)}{dY} \\ &- ak^2(-Y^2 + (\eta+1)Y - \eta)\frac{d}{dY}\left[(-Y^2 + (\eta+1)Y - \eta)\frac{dF}{dY}\right] = 0. \end{aligned} \tag{23.21}$$

After balancing the highest power of Y, we obtain that $2N + 1 = N + 2$, i.e., $N = 1$. Namely, $F(Y) = b_1 Y + b_0$. Substitute it into the equation Eq. (23.21) and do some algebra, we have the following

$$b_1 = -2ak, \quad b_0 = ak(\eta + 1) + V, \quad \forall \eta \in \mathbb{R},$$

or

$$u(x,t) = (ak(\eta + 1) + V) - 2ak \frac{e^{k(x-Vt)} + \eta e^{\eta k(x-Vt)}}{e^{k(x-Vt)} + e^{\eta k(x-Vt)}}$$

for $\eta \in \mathbb{R}$.

23.5 The Korteweg-de Vries (KdV) Equation

KdV equation is used in many sections of nonlinear mechanics and theoretical physics for describing one dimensional nonlinear dispersive nondissipative waves. Here, we consider the following KdV equation (see, e.g., [4]):

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + b \frac{\partial^3 u}{\partial x^3} = 0. \tag{23.22}$$

The positive parameter b refers to a dispersive effect. Here, we transform Eq. (23.22) into

$$-kV \frac{dU}{d\xi} + kU \frac{dU}{d\xi} + bk^3 \frac{d^3 U}{d\xi^3} = 0. \tag{23.23}$$

Then, we introduce

$$Y = \frac{e^{\xi} + \eta e^{\eta\xi}}{e^{\xi} + e^{\eta\xi}}, \quad \eta \in \mathbb{R},$$

and convert Eq. (23.23) into

$$\begin{aligned} & - kV(-Y^2 + (\eta + 1)Y - \eta) \frac{dF(Y)}{dY} + kF(Y)(-Y^2 + (\eta + 1)Y - \eta) \frac{dF(Y)}{dY} \\ & + bk^3(-Y^2 + (\eta + 1)Y - \eta) \frac{d}{dY} \Big\{ (-Y^2 + (\eta + 1)Y - \eta) \frac{d}{dY} \Big[(-Y^2 + (\eta \\ & + 1)Y - \eta) \frac{dF(Y)}{dY} \Big] \Big\} = 0. \end{aligned} \tag{23.24}$$

Now, balance the highest powers of Y, we obtain $2N + 1 = N + 3$, or $N = 2$. Now, in this problem, we search our solution as $F(Y) = a_0 + a_2 Y^2$, (i.e., we assume that the coefficient of Y is zero) and put this into the equation Eq. (23.24), and do some arrangements, at the end we have the following

$$\begin{aligned}
&Y^5(-24a_2bk^2 - 2a_2^2) + Y^4(54a_2bk^2(\eta+1) + 2a_2^2(\eta+1)) \\
&+ Y^3(-38a_2bk^2(\eta^2+1) - 116a_2bk^2\eta - 2a_2^2\eta - 2a_2a_0 + 2a_2V) \\
&+ Y^2(8a_2bk^2(\eta^3+1) + 76a_2bk^2\eta(\eta+1) + 2a_0a_2(\eta+1) - 2a_2(\eta+1)V) \\
&+ Y(-14a_2bk^2\eta(\eta^2+1) - 44a_2bk^2\eta^2 - 2a_2a_0\eta + 2a_2V\eta) \\
&+ 6a_2bk^2\eta^2(\eta+1) = 0. \qquad (23.25)
\end{aligned}$$

Equality Eq. (23.25) holds if each coefficient of the power of Y should be zero. As we realize from the last coefficient, $6a_1bk^2\eta^2(\eta+1) = 0$, i.e., $\eta = -1$ and from the first coefficient, we obtain $a_2 = -12bk^2$. Also, from the coefficient of Y^3, we get $a_0 = V + 8bk^2$. Hence, under these assumptions on η, a_2 and a_0 we have the equality Eq. (23.25). In this problem, we observe that $\eta = -1$ which makes our transformation to become tanh transformation. At the end we obtain our solution

$$u(x,t) = (V + 8bk^2) - 12bk^2\tanh^2(k(x - Vt)). \qquad (23.26)$$

23.6 The Landau–Ginburg–Higgs Equation

Now, we consider the following non-linear differential equation:

$$\frac{\partial^2 u}{\partial t^2} - \frac{\partial^2 u}{\partial x^2} - m^2u + n^2u^3 = 0, \qquad (23.27)$$

where m, n are real non-zero constants (e.g., see [7, 14]).

First of all, we convert the PDE Eq. (23.27) into ODE, i.e.,

$$k^2(V^2-1)\frac{d^2U(\xi)}{d\xi^2} - m^2U(\xi) + n^2U^3(\xi) = 0. \qquad (23.28)$$

Now, using our transformation, we get the following

$$\begin{aligned}
&k^2(V^2-1)(-Y^2 + (\eta+1)Y - \eta)\frac{d}{dY}\Big[(-Y^2 + (\eta+1)Y - \eta)\frac{dF}{dY}\Big] \\
&- m^2F + n^2F^3 = 0, \qquad (23.29)
\end{aligned}$$

where $F := F(Y) = \sum_{n=0}^{N} a_nY^n$. Balancing the highest powers of Y, we have $N + 2 = 3N$, or $N = 1$. Namely, we obtain $F(Y) = a_0 + a_1Y$. Now put $F(Y)$ into Eq. (23.29) and do some algebra, we have the following

$$Y^3(a_1^3n^2 - 2a_1k^2(1-V^2)) + Y^2(3a_1k^2(\eta+1)(1-V^2) + 3a_0a_1^2n^2) +$$
$$Y(3a_0^2a_1n^2 - a_1k^2(1-V^2)(4\eta+\eta^2+1) - a_1m^2) + \tag{23.30}$$
$$(a_1k^2\eta(\eta+1)(1-V^2) - a_0m^2 + a_0^3n^2) = 0.$$

Equality holds if and only if all coefficients of the Eq. (23.30) vanishes. Hence, after doing some calculations, we find that

$$a_1 = \pm\frac{2m}{n(\eta-1)}, \quad a_0 = \pm\frac{m(\eta+1)}{n(\eta-1)}, \quad k = \pm\frac{\sqrt{2}m}{(\eta-1)\sqrt{1-V^2}}, \tag{23.31}$$
$$\eta \neq 1, \quad V \neq \pm 1.$$

Also, one can easily prove that, for the case $V = \pm 1$, we have constant solution for Eq. (23.27). However, when $\eta = 1$ and $V \neq \pm 1$ in the equation Eq. (23.30), we get $m = 0$ which is not the case. Hence, no solution exists when $\eta = 1$.

23.7 Conclusion

In this paper, we introduce a new technique, by constructing a new transformation which is the general form of tanh transformation and then, by using our new form, we obtain exact solutions of some important non-linear partial differential equations related with medicine, biology [2, 12] and physics [13]. We see that our method is effective and more general than tanh method in the sense of getting the exact solutions of non-linear *PDEs*.

References

1. Ablowitz MJ, Clarkson PA (1991) Solitons, nonlinear evolution equations and inverse scattering. Cambridge University Press, Cambridge
2. Beuter A, Glass L et al (2013) Nonlinear dynamics in physiology and medicine. Springer Science & Business Media, Heidelberg
3. Coffey MW (1990) On series expansions giving closed-form solutions of Korteweg-de Vries-like equations. SIAM J Appl Math 50(6):1580–1592
4. Hereman W, Malfliet W (2005) The tanh method: a tool to solve nonlinear partial differential equations with symbolic software. In: 9th world multi-conference on systemics, cybernetics and informatics, pp 165–168
5. Hereman W, Takaoka M (1990) Solitary wave solutions of nonlinear evolution and wave equations using a direct method and MACSYMA. J Phys A: Math Gen 23(21):4805
6. Hereman W, Banerjee P et al (1986) Exact solitary wave solutions of nonlinear evolution and wave equations using a direct algebraic method. J Phys A: Math Gen 19(5):607
7. Khuri S (2008) Exact solutions for a class of nonlinear evolution equations: a unified Ansätze approach. Chaos, Solitons Fractals 36(5):1181–1188
8. Malfliet W (2004) The tanh method: a tool for solving certain classes of nonlinear evolution and wave equations. J Comput Appl Math 164:529–541

9. Malfliet W (2005) The tanh method: a tool for solving certain classes of non-linear PDES. Math Methods Appl Sci 28(17):2031–2035
10. Malfliet W, Hereman W (1996a) The tanh method: I. Exact solutions of nonlinear evolution and wave equations. Physica Scripta 54(6):563
11. Malfliet W, Hereman W (1996b) The tanh method: II. Perturbation technique for conservative systems. Physica Scripta 54(6):569
12. Murray J (1989) Mathematical Biology. Springer, Berlin
13. Polyanin AD, Zaitsev VF (2003) Handbook of nonlinear partial differential equations. CRC Press, Boca Raton
14. Taghizadeh N, Mirzazadeh M, Paghaleh AS (2012) The first integral method to nonlinear partial differential equations. Appl Appl Math 7(1):117–132
15. Whitham G (1974) Linear and nonlinear waves. Wiley, New York

Chapter 24
Stages and Processes of Self Change of Exercise Behavior: Toward an Integrative Model of Change

Xinyan Guo and Weiying Zhang

Abstract Used the Method of questionnaire survey, mathematic statistic, some urban residents were recruited and provided valid questionnaire data, to construct the integration model of exercise behavior, and test the stage discontinuity and the difference of exercise behavior variables across stages in integration model. The research results show below: (a) these subjects in same exercise stage had similar cognition degree of exercise barriers or difficulty, those subjects, however, in different stage had great different cognition degree of exercise; (b) the difference of different components was statistically significant between the various stages ($P < 0.05$) and also shown that the non-continuity of exercise behavior exist; (c) there were different in predicting effect of variables of integration model to the exercise behavior in different exercise stages. Then, the intervention method was provided based on stage discontinuity examination.

Keywords Exercise behavior · Stage discontinuity · Stage-matched intervention

24.1 Introduction

Studies and discussions on how to encourage regular physical exercises to the utmost extent have been dozens of years. Public medical institutions and the world health organization have already launched public health campaigns and taken intervention measures to deal with the problem of lacking physical exercises. In other words, the key value that physical exercise behavior holds to the national and public health, society and the country as wellis under estimated. Launching campaigns only to promote

X. Guo (✉)
Economy and Management Faculty, Chengdu Sport University, Chengdu 610041, People's Republic of China
e-mail: sindystory@163.com

W. Zhang
Foreign Language Faculty, Chengdu Sport Institute, Chengdu 610041, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_24

the benefits of exercises to the public is not enough to change people's behavior in doing exercises. Therefore, challenging the public health problem of physical exercise deficiency, designing and framing workable behavior intervention methods are key issues to be resolved. Based on these factors, this paper has a review and analysis on related documentations and materials of national and internal exercise behavior, behavior intervention and intervention experiments. Results show that current researches, though informative, are still in need of further studies. First, traditional intervention experiments focused on strategies of changing the exercise behavior and measuring the change of physical activity level after intervention, which are not control intervention based on exercise behavior period and change mechanism. The aim of this study is to construct integration model explaining exercise behavior of urban residents, and give them corresponding intervening measures.

24.2 Proposing of Integration Model of Urban Residents Exercise Behavior

Some research suggests that there are some conditions for model integration study of exercise behavior. The first, there should be a cross and overlap between different models in concept and content; the second, there should be scientific theory testing for integration; in addition, the choice of sample size should be adequate and scientific. Poss [6] discussed the development of the Health Belief Model and the Theory of Reasoned Action as the theoretic framework in tuberculosis screening, and other researcher tried apply this method to the field of exercise behavior [1–3, 10].

This study will integrate the health belief theory and the theory of planned behavior and propose that the exercise behavior outcome of urban resident can be predicted by some factors including behavioral attitude, body norm, perceived subjective control, perceived susceptibility, perceived severity, perceived behavior benefit, perceived behavior disorder, behavior clue and behavior intention. This study will construct a concept model about exercise behavior of urban resident Fig. 24.1.

24.3 Subjects and Methods

24.3.1 Participants

To ensure reasonable and integrity of research and data analysis, empirical research conducted in two phases: the first phase, baseline survey data analysis; the second phase, tracking data analysis.

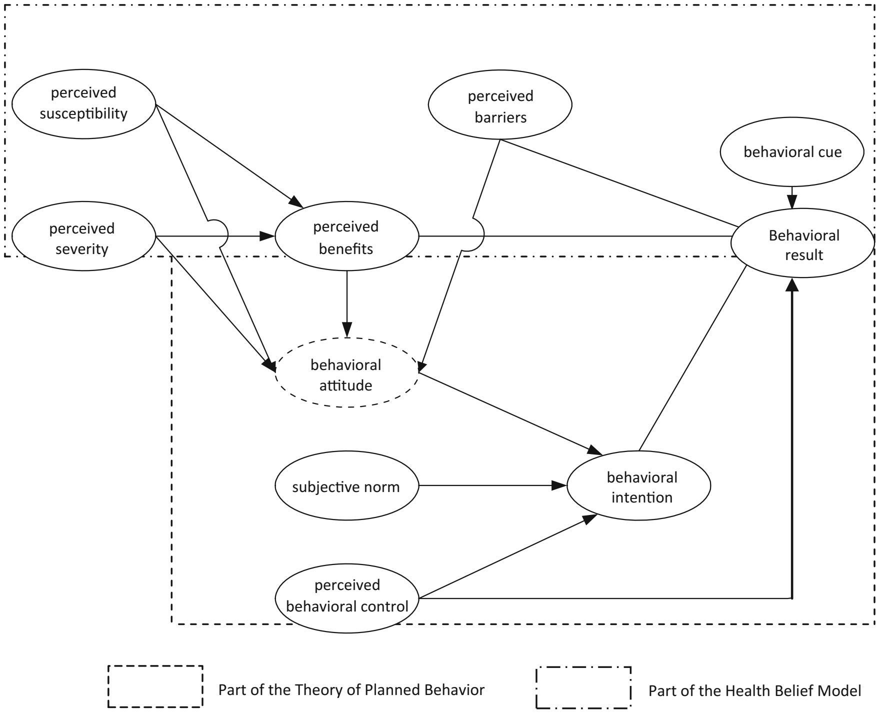


Fig. 24.1 Conceptual model of exercise behavior change

Table 24.1 Gender of respondents (baseline data) $N = 343$

Gender	%
Male	47.1
Female	52.9

Urban residents of Sichuan randomly selected for the survey sample ($n = 343$), and then the samples were randomly divided into two groups (165 people in intervention group and 178 people in control group), and the two subjects showed no significant difference in the results of exercise behavior and behavioral characteristics variables ($p > 0.05$) (Tables 24.1, 24.2, 24.3 and 24.4). Stage questionnaire of exercise behavior and integrating questionnaire of exercise behavior were distributed to individual and measured physical exercise behavior phase and basic information, and then the subjects were grouped by professional behavioral intervention staff.

After six month behavior intervention and tracking survey, behavioral test once every two months, four times totally, both groups use the same questionnaire scale.

Table 24.2 Age of respondents (baseline data) $N = 343$

Age	18	18–29	30–39	40–49	50–59	60
(%)	6.5	10.8	25.7	28.1	19.2	9.7

Table 24.3 Education of respondents (baseline data) $N = 343$

Elementary	School and below	Junior middle school	Senior high school	College	Postgraduate
%	4.9	10.5	25.2	38.1	21.3

Table 24.4 Occupation of respondents (baseline data) $N = 343$

	%
Student	10.5
Institution worker	22.3
Business and services practitioners	20.1
Retiree	11.6
Laid-off worker	20.2
Others	15.3

24.3.2 Instruments

A self-designed questionnaire was formed on the combination of the theory of planned behavior and health belief model, the questionnaire contain 4 items of personal basic information (including gender, age, occupation, education etc.), perceived susceptibility, perceived severity, perceived barriers, perceived benefits, behavioral cue, behavioral attitude, subjective norm, perceived behavioral control, behavioral intention and behavior, a total of 33 items. Scale by Likert five point scale method: among them, perceived barriers project assigned the remaining items reverse, positive score, namely “strongly disagree” for 1 points, “disagree” for 2 points, “not sure” for 3 points, “agreed” for 4 points, “strongly agree” for 5 points.

In this research, the reliability and validity of this questionnaire was examined, which the construct validity was examined by the factorial analysis and the internal reliability was examined by Cronbach α coefficient (Table 24.2). For testing the external reliability, 36 residents in Chengdu city were re-measured with the same scale after 4 weeks. The result shown that Pearson correlation coefficient was 0.89 ($P < 0.01$) and then this questionnaire had good validity and reliability.

24.4 Distribution of Correlated Characteristic Variable of Subjects in Different Behavior Stages

Phase division of exercise was based on the Stage of Change Theory [7]. According to the stage variation law, 10.9 % subjects were in the anterior intention stage, 23.6 % subjects were in intention stage, 36.4 % subjects were in action preparation stage, 20.6 % subjects were in action stage and 8.5 % subjects were in action maintain stage in intervention group before the intervention. There were 10.1, 24.2, 34.8, 21.3 and 9.6 % subjects respectively in control group.

The descriptive statistics results (Table 24.5) of different variable in different exercise stage shown that the residents had a higher cognition degree of exercise benefit ($M = 3.92$, $SD = 0.326$) than cognition degree of disorder ($M = 2.53$, $SD = 0.571$), the residents had higher score about attitude and behavior indentation in the stage of action maintenance, 4.82 and 4.73 score respectively. However they had lower score about perceived behavioral control, perceived severity, perceived susceptibility and behavioral intention in anterior intention stage.

24.5 Non-continuity Test of Variable About Stage Distribution in Integration Model

According to the studies, the subjects at same exercise stage had similar cognition degree of exercise barriers or difficulties, whereas subjects at different stages showed a variety of cognition degrees of exercise. Some of the studies demonstrated that behavior stages exist when the identical variable of social psychology has different explanation effects on different behavior stages [4]. Some studies on exercise stage theory exploring the intervention of stage matching and non-stage matching [5, 8, 9] have also proved that the non-continuity of exercise behavior variable exist at different stages.

24.5.1 Difference of Variable in The Stage Distribution of Integration Model

For further exploring the difference of various subscales between the exercise stages, the various subscales were tested by OneWay ANOVA, the result shown that the difference of different components was statistically significant between the various stages ($P < 0.05$) and also shown that the non-continuity of exercise behavior exist (Table 24.6).

Table 24.5 The mean and standard deviation of variables in different stages $\overline{x} \pm s$

Component	Exercise stages					
	Anterior intention stage	Intention stage	Preparatory stage	Action stage	Maintenance stage	n
Behavioral cue	2.83 ± 0.231	3.98 ± 0.438	3.45 ± 0.393	2.88 ± 0.160	2.37 ± 0.431	3.10 ± 0.199
Perceived severity	2.39 ± 0.320	3.71 ± 0.106	3.70 ± 0.356	4.15 ± 0.129	4.35 ± 0.680	3.66 ± 0.219
Perceived susceptibility	2.44 ± 0.199	2.85 ± 0.480	3.90 ± 0.580	4.36 ± 0.105	4.40 ± 0.486	3.59 ± 0.688
Perceived barriers	3.61 ± 0.589	3.04 ± 0.114	2.28 ± 0.449	2.03 ± 0.233	1.67 ± 0.306	2.53 ± 0.571
Perceived benefits	2.78 ± 0.480	3.85 ± 0.690	4.11 ± 0.541	4.30 ± 0.562	4.54 ± 0.590	3.92 ± 0.326
Behavioral attitude	2.70 ± 0.166	3.88 ± 0.559	3.92 ± 0.582	4.58 ± 0.579	4.82 ± 0.469	3.98 ± 0.498
Subjective norm	2.61 ± 0.327	3.11 ± 0.673	3.94 ± 0.467	4.44 ± 0.570	4.60 ± 0.694	3.74 ± 0.784
Perceived behavioral control	1.83 ± 0.098	2.79 ± 0.402	3.24 ± 0.151	4.35 ± 0.807	4.68 ± 0.561	3.38 ± 0.272
Behavioral intention	2.64 ± 0.398	3.28 ± 0.587	3.84 ± 0.308	4.51 ± 0.573	4.73 ± 0.560	3.80 ± 0.294

Table 24.6 The results of factor analysis of ANOVA in different exercise stages

Component	F value	P value
Behavioral cue	3.738	0.005 ∗∗
Perceived severity	9.069	0.000 ∗∗
Perceived susceptibility	8.261	0.000 ∗∗
Perceived barriers	7.595	0.000 ∗∗
Perceived benefits	4.246	0.002 ∗∗
Behavioral attitude	36.206	0.000 ∗∗
Subjective norm	14.534	0.000 ∗∗
Perceived behavioral control	23.248	0.000 ∗∗
Behavioral intention	27.885	0.000 ∗∗

∗the difference is significant at 0.05 level
∗∗the difference is significant at 0.01 level

24.5.2 Non-continuity Characteristics and Analysis of Variable About Stage Distribution in Integration Model

This study had analyzed these variables in integration model on the anterior intention stage, intention stage, preparatory stage, action stage and maintenance stage, respectively, to test the stages existence of integration model by rank regression method. The statistical result of rank regression indicated that there were different in predicting effect of variables of integration model to the exercise behavior in different exercise stages (Table 24.7).

In the anterior intention stage, there was a positive correlation between behavioral cue, behavioral barriers and exercise behavior; and there was a negative correlation between perceived susceptibility, perceived severity, perceived benefits, attitude, perceived behavioral control and behavioral intention; and significant predicting variables included perceived severity, perceived susceptibility, perceived benefits and behavioral barriers; and the rest variables belonged to non significant predicting variables. This result can explain 25.9 % of exercise behavior variation ($R^2 = 0.259$).

In the intention stage, there was a negative correlation between perceived severity, perceived susceptibility and exercise behavior; and the rest variables had a positive correlation with exercise behavior; and the behavioral cue and attitude belonged to significant predicting variables; the rest variables belonged to non significant predicting variables. This result can explain 27 % of exercise behavior variation ($R^2 = 0.270$).

In the preparatory stage, behavioral barriers had a negative correlation with exercise behavior; and the rest variables had a positive correlation with exercise behavior; and significant predicting variables included behavioral cue, behavioral barriers, behavioral attitude, subjective norm, and behavioral intention; and the rest variables

Table 24.7 Discrepancy of model component in different stages

Component	β					
	Anterior intention stage	Intention stage	Preparatory stage	Action stage	Maintenance stage	*n*
Behavioral cue	0.101	0.129*	0.142**	0.105	0.096	0.101
Perceived severity	−0.156**	−0.071	0.018	0.114	0.131*	−0.156**
Perceived susceptibility	−0.205**	−0.073	0.103	0.130*	0.143**	−0.205**
Perceived barriers	0.132*	0.053	−0.122*	−0.099	−0.102	0.132*
Perceived benefits	−0.175**	0.099	0.107	0.112	0.115	−0.175**
Behavioral attitude	−0.053	0.130*	0.145**	0.151**	0.164**	−0.053
Subjective norm	−0.095	0.051	0.131*	0.140**	0.113	−0.095
Perceived behavioral control	−0.076	0.039	0.101	0.148**	0.159**	−0.076
Behavioral intention	−0.045	0.057	0.132*	0.142**	0.204**	−0.045

* the difference is significant at 0.05 level
** the difference is significant at 0.01 level

belonged to non significant predicting variables. This result can explain 36.1 % of exercise behavior variation ($R^2 = 0.361$).

In the action stage, behavioral barriers had a negative correlation with exercise behavior; and the rest variables had a positive correlation with exercise behavior; and significant predicting variables included perceived susceptibility, behavioral attitude, subjective norm, perceived behavioral control and behavioral intention; the rest variables belonged to non significant predicting variables. This result can explain 25.1 % of exercise behavior variation ($R^2 = 0.251$).

In the maintenance stage, behavioral barriers had a negative correlation with exercise behavior; and the rest variables had a positive correlation with exercise behavior; and significant predicting variables included perceived severity, perceived susceptibility, behavioral attitude, subjective norm, perceived behavioral control and behavioral intention; the rest variables belonged to non significant predicting variables. This result can explain 31.4 % of exercise behavior variation ($R^2 = 0.314$).

24.6 Analysis and Discussion

The result of non-continuity analysis to individual exercise behavioral stages shown that there were different in predicting effect of behavioral characteristic variables to the exercise behavioral stages, which provided sufficient evidence for the existing of exercise behavioral stages in different age, gender, cultural background and individual behavior. This study indicated that individual in different stage had different psychological cognitive status and behavior intention level, and faced different difficulties and obstacles. So we should adopt stage matching intervention method based on different stage of individual behavior.

For the anterior intention stage, significant predicting variables include perceived severity, perceived susceptibility, perceived benefits and behavioral barriers. So it is more important to obtain knowledge about benefits of exercise participation and dangers of lack of exercise, which may be enhance exercise intention and promote exercise participation.

For the intention stage, the behavioral cue and attitude belonged to significant predicting variables. In the stage, individuals have realized the benefits of exercise, and exercise knowledge exchange can be used as an adjunct method. The exercise cue is a kind of external factor. So proper exercise guidance is the main intervention, such as making exercise plan and exercise prescription, overcoming the psychological barriers.

For the preparatory stage, significant predicting variables included behavioral cue, behavioral barriers, behavioral attitude, subjective norm, and behavioral intention. In the stage, individuals have an exercise plan and intention, but they need to choice an appropriate exercise which can be influenced by external factors, such as very important person for them. So subjective norm is an important predicting variable which indicate these subjects need a depth interview and psychology guidance to establish an important position in their exercise behavior consciousness.

In the action stage, significant predicting variables included perceived susceptibility, behavioral attitude, subjective norm, perceived behavioral control and behavioral intention. In the stage, it is an important link from intention to action when individuals gradually formed inner awareness and motivation during exercise. So the main intervention should focus on the prevention of stage backwards and strengthening attitude by exemplary role and contrast to enhance individual confidence of regular physical exercise.

In the maintenance stage, the individuals have completed at least six months of regular physical exercise, and they have a clear understanding and independent thinking and decision-making skills for exercise behavior. External factors such as behavioral cues, behavioral disorders have been insufficient to have a decisive impact on their exercise behavior. So it should take an kind of exemplary strengthening way. In addition, their physical health indicators should be tested and contrasted to enhance their awareness of the perceived severity and perceived susceptibility for better intervention effect.

References

1. Courneya KS, Bobick TM (2000) Integrating the theory of planned behavior with the processes and stages of change in the exercise domain. Psychol Sport Exerc 1(1):41–56
2. Jackson KM, Aiken LS (2000) A psychosocial model of sun protection and sunbathing in young women: the impact of health beliefs, attitudes, norms, and self-efficacy for sun protection. Health Psychol 19(5):469
3. Kautonen T, Gelderen M, Fink M (2013) Robustness of the theory of planned behavior in predicting entrepreneurial intentions and actions. Entrep Theory Pract 39(3):655–674
4. Lippke S, Ziegelmann JP, Schwarzer R (2005) Stage-specific adoption and maintenance of physical activity: testing a three-stage model. Psychol Sport Exerc 6(5):585–603
5. Nigg CR (2003) Technology's influence on physical activity and exercise science: the present and the future. Psychol Sport Exerc 4(1):57–65
6. Poss JE (2001) Developing a new model for cross-cultural research: synthesizing the health belief model and the theory of reasoned action. Adv Nurs Sci 23(4):1–15
7. Prochaska JO, DiClemente CC (1983) Stages and processes of self change of smoking: toward an integrative model of change. J Consult Clin Psychol 51(3):390–395
8. Schwarzer R (2008a) Modeling health behavior change: how to predict and modify the adoption and maintenance of health behaviors. Appl Psychol 57(1):1–29
9. Schwarzer R (2008b) Models of health behaviour change: intention as mediator or stage as moderator? Psychol Health 23(3):259–263
10. Straub CL, Leahy JE (2014) Application of a modified health belief model to the pro-environmental behavior of private well water testing. JAWRA J Am Water Resour Assoc 50(6):1515–1526

Chapter 25
An Intuitionistic Fuzzy ELECTRE-III Method for Credit Risk Assessment

Feng Shen, Dao Lan and Zhiyong Li

Abstract Multi-criteria decision making (MCDM) is a widely efficient decision methodology, which has successfully been used to diverse scientific fields. In this paper, an intuitionistic fuzzy ELECTRE-III approach is proposed to solve the MCDM problem. We combine the ELECTRE-III method with intuitionistic fuzzy information in an integrated approach. Finally, a case study of credit risk assessment is provided to elucidate the details of the proposed method.

Keywords Multi-criteria decision making · Intuitionistic fuzzy set · ELECTRE-III method · Credit risk assessment

25.1 Introduction

Multiple criteria decision making (MCDM) is an effective framework to evaluate a set of alternatives using several criteria independent of each other. It has thus been widely applied to various fields [4]. During the MCDM process, decision maker needs to evaluate the performance of each alternative with respect to each criterion. However, in real life, it is not easy to acquire precise assessment information due to the uncertainty and limitation of human judgment. Zadeh [9] proposed the fuzzy set theory which is an effective tool to deal with the uncertainty. Specifically, intuitionistic fuzzy sets (IFSs) introduced by Atanassov [1] have been found to be highly useful in dealing with fuzziness. ELECTRE is one of the well known MCDM methods [6]. It is a comprehensive evaluation method family. Specially, Electre-III is a ranking method that uses pseudo-criteria and fuzzy binary outranking relations.

F. Shen · Z. Li
School of Finance, Southwestern University of Finance and Economics, Chengdu 611130, People's Republic of China

D. Lan (✉)
Southwestern University of Finance and Economics, Chengdu 611130, People's Republic of China
e-mail: landao@swufe.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_25

In this study, we combine the ELECTRE-III method with intuitionistic fuzzy information in an integrated approach so as to solve a multi-criteria decision making problem. This paper is organized as follows: In Sect. 25.2, we introduce the concepts of the ELECTRE-III method and intuitionistic fuzzy set. In Sect. 25.3, we present the intuitionistic fuzzy ELECTRE-III approach framework. For illustration and verification purposes, Sect. 25.4 presents a case study of credit risk assessment to illustrate the details of the method. Finally, conclusion is given in Sect. 25.5.

25.2 Preliminary Definitions

In this section, we first give a brief introduction to some concepts for intuitionistic fuzzy set and ELECTRE-III method.

Atanassov [1] proposed the concept of intuitionistic fuzzy set (A-IFS):

Definition 25.1 Let $X = \{x_1, x_2, \ldots, x_n\}$ be fixed. An intuitionistic fuzzy set (IFS) A in X can be defined as:

$$A = \{(x_i, \mu_A(x_i), \nu_A(x_i))|x_i \in X\}, \tag{25.1}$$

where the functions $\mu_A(x_i)$ and $\nu_A(x_i)$ denote the membership degree and the non-membership degree of x_i to A in X with the condition that $0 \le \mu_A(x_i) \le 1, 0 \le \nu_A(x_i) \le 1, 0 \le \mu_A(x_i) + \nu_A(x_i) \le 1$ and $\pi_A = 1 - \mu_A(x_i) - \nu_A(x_i)$ is the intuitionistic index (or hesitation degree) of x_i to A.

Xu [7] named $(\mu_\alpha, \nu_\alpha, \pi_\alpha)$ an intuitionistic fuzzy number (IFN) denoted as α with the condition that $0 \le \mu_\alpha \le 1, 0 \le \nu_\alpha \le 1, 0 \le \mu_\alpha + \nu_\alpha \le 1$ and $\pi_\alpha = 1 - \mu_\alpha - \nu_\alpha$. Especially, if $\mu_\alpha + \nu_\alpha = 1$, then α reduces to $(\mu_\alpha, 1 - \mu_\alpha)$.

The score function $s(\alpha)$ [3] which is used to measure the score of α and the accuracy function $h(\alpha)$ [5] which is used to evaluate the accuracy degree of α are defined as:

$$s(\alpha) = \mu_\alpha - \nu_\alpha, \tag{25.2}$$

$$h(\alpha) = \mu_\alpha + \nu_\alpha. \tag{25.3}$$

Based on the score function $s(\alpha)$ and the accuracy function $h(\alpha)$, Xu and Yager [8] gave an order relation between any two IFNs α and β:

Definition 25.2 Let $\alpha = (\mu_\alpha, \nu_\alpha, \pi_\alpha)$ and $\beta = (\mu_\beta, \nu_\beta, \pi_\beta)$ be the IFNs, $s(\alpha)$ and $h(\alpha)$ be the scores and accuracy degrees of α and β, respectively, then

- If $s(\alpha) < s(\beta)$, then $\alpha < \beta$;
- If $s(\alpha) > s(\beta)$, then $\alpha > \beta$;
- If $s(\alpha) = s(\beta)$, then

(i) If $h(\alpha) < h(\beta)$, then $\alpha < \beta$;
(ii) If $h(\alpha) > h(\beta)$, then $\alpha > \beta$;
(iii) If $h(\alpha) = h(\beta)$, then $\alpha = \beta$.

In order to measure the deviation between any two IFNs $\alpha = (\mu_\alpha, \nu_\alpha, \pi_\alpha)$ and $\beta = (\mu_\beta, \nu_\beta, \pi_\beta)$, Xu [7] defined a distance measure between two IFNs.

Definition 25.3 Let $\alpha = (\mu_\alpha, \nu_\alpha, \pi_\alpha)$ and $\beta = (\mu_\beta, \nu_\beta, \pi_\beta)$ be two IFNs, then

$$d_{IFN}(\alpha, \beta) = \sqrt{\frac{1}{2}\left(\left(\mu_\alpha - \mu_\beta\right)^2 + \left(\nu_\alpha - \nu_\beta\right)^2 + (\pi_\alpha - \pi_\beta)^2\right)} \tag{25.4}$$

is called an intuitionistic fuzzy distance between α and β.

ELECTRE-III is a multi-criteria decision making method based on outranking relations for dealing with some complex ranking problems [6]. In ELECTRE-III method, the outranking relation is defined by a concordance index and a discordance index for each criterion c_j in C. Then, through the exploitation of the outranking relation, the ranking result is obtained. For further details on the method, see [6].

25.3 Intuitionistic Fuzzy ELECTRE-III Approach Framework

Most multi-criteria decision-making problems can be described using the following sets:

(1) A set of m alternatives called $A = \{a_1, a_2, \ldots, a_m\}$;
(2) A set of n criteria called $C = \{c_1, c_2, \ldots, c_n\}$;
(3) A set of n criteria weights called $W = \{w_1, w_2, \ldots, w_n\}$;
(4) A set of performance ratings of $a_i (i = 1, 2, \ldots, m)$ on criteria $c_j (j = 1, 2, \ldots, n)$ called $X = (x_{ij})_{m\times n}$.

In this section, we propose an intuitionistic fuzzy ELECTRE III method, which is a type of ELECTRE III method used for dealing with intuitionistic fuzzy evaluation information. In construction phase, the intuitionistic fuzzy outranking degree is constructed. It is obtained by both the intuitionistic fuzzy concordance degree and the intuitionistic fuzzy discordance degree.

Definition 25.4 Let A be a set of alternatives, for $\forall\ a_i, a_k \in A$, the intuitionistic fuzzy concordance degree $g\ (a_i, a_k)$ indicates the credibility proposition of a_i over a_k, and is defined as:

$$g\ (a_i, a_k) = \sum\nolimits_{i=1}^{n} w_j c_j\ (a_i, a_k), \tag{25.5}$$

where $\sum_{i=1}^{n} w_j = 1$,

$$g_j\left(a_i, a_k\right) = \begin{cases} 1, & \text{if } \widetilde{x}_{ij} + q_j \geq \widetilde{x}_{kj}, \\ 0, & \text{if } \widetilde{x}_{ij} + p_j \leq \widetilde{x}_{kj}, \\ \frac{\widetilde{x}_{ij} + p_j - \widetilde{x}_{kj}}{p_j - q_j}, & \text{otherwise}, \end{cases} \tag{25.6}$$

and

$$\widetilde{x}_{ij} = \begin{cases} d_{\text{IFN}}\left(x_{ij}, \alpha^-\right), & \text{if } c_j \in C^+, \\ d_{\text{IFN}}\left(x_{ij}, \alpha^+\right), & \text{if } c_j \in C^-, \end{cases} \tag{25.7}$$

in which, α^+ is the positive ideal point (1,0,0), α^- is the negative ideal point (0,1,0), C^+ is the set of benefit criteria and C^- is the set of cost criteria.

The intuitionistic fuzzy concordance degree matrix G is defined as follows:

$$G = \begin{bmatrix} - & \cdots & g_{1k} & \cdots & g_{1(m-1)} & g_{1m} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \vdots \\ g_{i1} & \cdots & g_{ik} & \cdots & g_{i(m-1)} & g_{im} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \vdots \\ g_{m1} & \cdots & g_{mk} & \cdots & g_{m(m-1)} & - \end{bmatrix}, \tag{25.8}$$

where $g_{ik} = g(a_i, a_k)$.

Definition 25.5 Let A be a set of alternatives and C be a set of criteria, for $\forall\, a_i, a_k \in A$ and $\forall\, c_j \in C$, the intuitionistic fuzzy discordance degree $f_j\left(a_i, a_k\right)$ indicates the credibility of the proposition "a_i is not at least as good as a_k", and is defined as:

$$f_j\left(a_i, a_k\right) = \begin{cases} 0, & \text{if } \widetilde{x}_{ij} + p_j \geq \widetilde{x}_{kj}, \\ 1, & \text{if } \widetilde{x}_{ij} + v_j \leq \widetilde{x}_{kj}, \\ \frac{\widetilde{x}_{kj} - p_j - \widetilde{x}_{ij}}{v_j - p_j}, & \text{otherwise}, \end{cases} \tag{25.9}$$

where

$$\widetilde{x}_{ij} = \begin{cases} d_{\text{IFN}}\left(x_{ij}, \alpha^-\right), & \text{if } c_j \in C^+, \\ d_{\text{IFN}}\left(x_{ij}, \alpha^+\right), & \text{if } c_j \in C^-, \end{cases} \tag{25.10}$$

in which, α^+ is the positive ideal point (1,0,0), α^- is the negative ideal point (0,1,0), C^+ is the set of benefit criteria and C^- is the set of cost criteria.

Definition 25.6 The intuitionistic fuzzy outranking degree $h\left(a_i, a_k\right)$ aggregates the concordance and discordance degrees in order to measure the outranking intensity, and is defined as:

$$h\left(a_i, a_k\right) = \begin{cases} c\left(a_i, a_k\right), & \text{if } f_j\left(a_i, a_k\right) \le c\left(a_i, a_k\right)\ \forall j, \\ c\left(a_i, a_k\right) \prod\limits_{j \in J\left(a_i, a_k\right)} \frac{1 - f_j\left(a_i, a_k\right)}{1 - c\left(a_i, a_k\right)}, & \text{otherwise,} \end{cases} \tag{25.11}$$

where $J\left(a_i, a_k\right)$ is the set of criteria for $f_j\left(a_i, a_k\right) > c\left(a_i, a_k\right)$.

Then, the intuitionistic fuzzy outranking matrix H is defined as follows:

$$H = \begin{bmatrix} - & \dots & h_{1k} & \dots & h_{1(m-1)} & h_{1m} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \vdots \\ h_{i1} & \dots & h_{ik} & \dots & h_{i(m-1)} & h_{im} \\ \vdots & \ddots & \vdots & \ddots & \vdots & \vdots \\ h_{m1} & \dots & h_{mk} & \dots & h_{m(m-1)} & - \end{bmatrix}, \tag{25.12}$$

where $h_{ik} = h(a_i, a_k)$.

In exploitation phase, the net outranking flows are calculated in a way similar to the PROMETHEE method produces a total preorder [2].

Definition 25.7 The net outranking flow degree $\Phi(a_i)$ $(i = 1, 2, \dots, m)$ represents the net outranking character of a_i over all the remaining alternatives, and is defined as:

$$\Phi(a_i) = \sum_{k=1, k \neq i}^{m} r\left(a_i, a_k\right), \tag{25.13}$$

where

$$r(a_i, a_k) = h\left(a_i, a_k\right) - h\left(a_k, a_i\right) \tag{25.14}$$

The alternatives can be ranked according the net outranking flows in a descending order. The algorithm for the proposed intuitionistic fuzzy outranking ranking method framework is developed by the below steps.

Step 1. The experts construct the credit evaluation decision matrix $X = (x_{ij})_{m \times n}$ with intuitionistic fuzzy evaluation information.

Step 2. The experts identify relevant thresholds of the proposed model q_j, p_j, v_j.

Step 3. Using Eqs. (25.5)–(25.8), calculate the intuitionistic fuzzy concordance degree matrix $C = (c_{ij})_{m \times n}$.

Step 4. Next, the intuitionistic fuzzy outranking matrix $H = (h_{ij})_{m \times n}$ is calculated by Eqs. (25.9)–(25.12).

Step 5. Calculate the net flow degrees $\Phi(a_i)$ $(i = 1, 2, \dots, m)$ using Eq. (25.13). The alternatives can be then ranked according to the net flow degrees.

Step 6. End.

25.4 Case Study

A financial company intends to evaluate the credit risk of its five strategic partners $(a_1, a_2, a_3, a_4, a_5)$. According to the company's development strategy, the company manager decided on four criteria to evaluate the five strategic partners: Organization Factor (c_1), Economic Factor (c_2), Financial Factor (c_3) and Management Factor (c_4). The manager allocated the criteria weight vector $W = (0.31, 0.26, 0.23, 0.20)^{\mathrm{T}}$. Over the course of the decision evaluation, the experts may have been unable to be confident about their judgments. To deal with this fuzziness, the experts' preference values were expressed using IFNs. The procedure for the credit assessment of the five strategic partners was performed as in the following steps:

Step 1. The experts gave their own opinions about the performance of a_i for each criterion c_j. They constructed the credit assessment matrix with the intuitionistic fuzzy evaluation information in Table 25.1.

Step 2. The experts identified the relevant thresholds of the proposed model q, p, v. The relevant thresholds are shown in Table 25.2.

Step 3. Using Eqs. (25.5)–(25.8), the intuitionistic fuzzy concordance degree matrix G was respectively calculated as follows:

$$G = \begin{bmatrix} - & 0.567 & 0.496 & 0.941 & 1.000 \\ 0.725 & - & 0.486 & 0.826 & 1.000 \\ 0.772 & 0.514 & - & 0.713 & 0.948 \\ 0.795 & 0.496 & 0.000 & - & 1.000 \\ 0.567 & 0.217 & 0.000 & 0.724 & - \end{bmatrix}.$$

Step 4. Next, Eqs. (25.9)–(25.12) were used to construct the intuitionistic fuzzy outranking matrix H as follows:

Table 25.1 The credit assessment matrix with intuitionistic fuzzy information

	c_1	c_2	c_3	c_4
a_1	(0.45,0.55,0.00)	(0.40,0.55,0.05)	(0.70,0.30,0.00)	(0.70,0.20,0.10)
a_2	(0.50,0.40,0.10)	(0.70,0.30,0.00)	(0.60,0.40,0.00)	(0.60,0.35,0.05)
a_3	(0.70,0.25,0.05)	(0.40,0.55,0.05)	(0.40,0.55,0.05)	(0.90,0.10,0.00)
a_4	(0.40,0.55,0.05)	(0.50,0.50,0.00)	(0.70,0.25,0.05)	(0.60,0.40,0.00)
a_5	(0.40,0.60,0.00)	(0.40,0.50,0.10)	(0.50,0.50,0.00)	(0.50,0.45,0.05)

Table 25.2 The relevant thresholds

q	p	v
0.05	0.15	0.30

Table 25.3 The net outranking flow degree values

	a_1	a_2	a_3	a_4	a_5
$\Phi(a_i)$	−0.366	1.805	1.326	−0.215	−2.549

Table 25.4 The preorder of five strategic partners

a_1	a_2	a_3	a_4	a_5
4	1	2	3	5

$$H = \begin{bmatrix} - & 0.237 & 0.155 & 0.941 & 1.000 \\ 0.725 & - & 0.167 & 0.826 & 1.000 \\ 0.613 & 0.071 & - & 0.015 & 0.948 \\ 0.795 & 0.496 & 0.000 & - & 1.000 \\ 0.567 & 0.108 & 0.000 & 0.724 & - \end{bmatrix}.$$

Step 5. Table 25.3 presents the results of the net outranking flow degree values on five strategic partners using Eq. (25.13).

Next, the preorder according the net outranking flow degree values on five strategic partners was determined as shown in Table 25.4.

25.5 Conclusion

MCDM is an effective framework to evaluate a set of alternatives using several criteria independent of each other. In this paper, we provided an intuitionistic fuzzy ELECTRE-III approach to solve the credit risk assessment problem. This approach is easy to understand and adopt for managers. In the future study, we will use the proposed method for other MCDM problems. Another direction will be the employment of other types of fuzzy sets.

Acknowledgments Supported by the Fundamental Research Funds for the Central Universities (Grant No. 112010004005080004).

References

1. Atanassov KT (1986) Intuitionistic fuzzy sets. Fuzzy Sets Syst 20(1):87–96
2. Bouyssou D (1992) Ranking methods based on valued preference relations: a characterization of the net flow method. Eur J Oper Res 60(1):61–67
3. Chen SM, Tan JM (1994) Handling multicriteria fuzzy decision-making problems based on vague set theory. Fuzzy Sets Syst 67(2):163–172

4. Govindan K, Jepsen MB (2016) ELECTRE: a comprehensive literature review on methodologies and applications. Eur J Oper Res 250(1):1–29
5. Hong DH, Choi CH (2000) Multicriteria fuzzy decision-making problems based on vague set theory. Fuzzy Sets Syst 114(1):103–113
6. Roy B (2013) Multicriteria methodology for decision aiding, vol 12. Springer Science & Business Media, New York
7. Xu Z (2013) Intuitionistic fuzzy aggregation and clustering, vol 279. Springer, Heidelberg
8. Xu Z, Yager RR (2006) Some geometric aggregation operators based on intuitionistic fuzzy sets. Int J Gen Syst 35(4):417–433
9. Zadeh LA (1965) Fuzzy sets. Inf Control 8(3):338–353

Chapter 26
A Dynamic Programming-Based Genetic Algorithm for a Joint Pricing Construction Materials Procurement Problem with Uncertainties

Kai Kang, Shuyue Zhou, Yanfang Ma and Xuguang Wei

Abstract In this paper, a dynamic programming model is proposed for a joint pricing construction materials procurement problem with multiple suppliers (JPCMPPMS) in a fuzzy random environment. In this model, the objective of the leader is to minimize total costs by deciding the purchase quantity. Demand and transport price are assumed to be fuzzy random variables in this paper. A dynamic programming-based genetic algorithm (DP-based GA) is developed to find feasible solutions and a dynamic programming-based initialization, crossover and mutation are designed to avoid infeasible solutions. The model and the proposed solution procedure are very practical and effective, and raw material purchasing system will achieve the overall best economic interests.

Keywords Construction materials procurement · Multiple suppliers · Genetic algorithm · Fuzzy random variables

26.1 Introduction

Construction materials procurement plays an important role in construction projects. In recent years, along with economic globalization and the rapid development of the logistics industry, procurement has received increased attention in practice. For efficient operations, a construction material procurement, which is directly related to the project cost and quality, must be prepared to service for the entire project so that construction projects can maximize its profits.

Much of the past studies on construction materials procurement have been limited to a fixed price. Such as Chen [1] and Hu [5] discussed a model with a fixed price.

K. Kang · S. Zhou · Y. Ma (✉) · X. Wei
School of Economics and Management, Hebei University of Technology,
Tianjin 300401, People's Republic of China
e-mail: mayanfang@hebut.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_26

However, in the real world, the prices of materials are changing over time during the whole construction duration. So, a new method to establish the purchase price is used in this paper. Thus, based on previous studies, with the consideration of joint pricing-procurement in practice, a new dynamic programming model is proposed for the joint pricing construction materials procurement problem with multiple suppliers (JPCMPPMS).

In construction projects, there are many uncertainties [7]. Thus, in order to move closer to actual situation, these uncertainties must be considered in the JPCMPPMS. In general, there are many unforeseen circumstances in construction projects such as equipment breakdown, changing weather, labor inefficiency, and lack of coordination among workers [7]. These uncertainties have generally been considered to be random variables. However, fuzziness, another type of uncertainty is gradually expressing its adaptability and rationality to some real projects, and random uncertainty and fuzzy uncertainty can exist in the same project sometimes. In this paper, the JPCMPPMS is studied under a fuzzy random environment.

In summary, based on previous studies, a joint pricing construction materials procurement problem with multiple suppliers (JPCMPPMS) in a fuzzy random environment is proposed. In the proposed formulation, the JPCMPPMS is considered a pricing formula and multiple suppliers. In the model, all costs involved in the JPCMPPMS have been considered and classified clearly. Fuzzy random theory is used to describe JPCMPPMS demand quantity and transportation price. In recent years, a number of researchers have started to proposed various heuristic techniques such as the genetic algorithm (GA) [8], particle swarm optimization [4], tabu search [2]. Among these algorithms, GA is a recently-proposed population-based stochastic optimization algorithm. Since the traditional methods are not suitable for solving large or difficult models, and, there are still seldom researches developing an effective heuristic algorithm for solving the raw materials procurement problems in a large scale construction project under a fuzzy random environment, a new algorithm, the dynamic programming based genetic algorithm (DP-based GA), is proposed in this paper.

The remainder of this paper is organized as follows: in Sect. 26.2, the key problems description for the JPCMPPMS are described, and the JPCMPPMS mathematical formulation model is presented. In Sect. 26.3, a genetic algorithm with a fuzzy random simulation is proposed to solve the model. Concluding remarks are given in Sect. 26.4.

26.2 Key Problem Description

For description convenience, the following variables are defined.

N: The number of suppliers;
J: The number of raw materials species;
L: The number of impurity compositions;

x_{ij}: The total purchase quantity of the jth raw material from the ith supplier, where $i = 1, 2, \ldots, N$, $j = 1, 2, \ldots, J$;
$O^{Q\min}$: The minimum purchase quantity of the jth raw material from the ith supplier;
$O^{Q\max}$: The maximum purchase quantity of the jth raw material from the ith supplier;
p_{ij}: The purchase price of the jth raw material from the ith supplier;
Q_{ij}: The main composition percentage of the jth raw material from the ith supplier;
Q^*: The minimum percentage of main composition of total raw material purchased;
q^*: The minimum total quantity of main composition of total raw material purchased;
$D_{k,ij}$: The kth impurity percentage of the jth raw material from the ith supplier, where $k = 1, 2, \ldots, L$;
D_k^*: The kth impurity maximum percentage of total raw material purchased;
f_i: The fixed activity cost for the ith supplier of one order;
t_{io}: The order processing time for the ith supplier;
t_i: The transportation time from the ith supplier to the producer;
$\tilde{\bar{b}}_i$: The transportation cost of unit distance and unit quantity from the ith supplier, and it is assumed to be fuzzy random;
b_{io}: The fixed part of transportation cost from the ith supplier;
h: The producer's storage cost of unit time and unit quantity;
T: Inventory inspection cycle, for $i = 1, 2, \ldots, N$, there is $T > t_{io} + t_i$;
I_j: The jth raw material inventory;
$\tilde{\bar{U}}_j$: The demand of the jth raw material, and it is assumed to be fuzzy random;
Z_i: If a deal occurred for the ith supplier then $Z_i = 1$; else, $Z_i = 0$;
$R(m_{ij})$: The tax cost of Purchase the jth raw materials from the ith suppliers;
i: The supplier indices;
j: The raw materials indices;
o: The order indices;
m: The stage indices;
ξ_j: Safety stock violation penalty for raw material j;
$I_j^{\min}$: Safety stock for raw material j;
$I_j^{\max}$: The maximum inventory level of the jth raw material;
s_i: The distance with the ith supplier.

26.2.1 Research Problem Description

Purchasing processes may be divided into different phases. These are mainly competitive biding, order, storage and transportation phases. In the competitive-biding phase as the first process, suppliers must comply with regulations based on international engineering bidding and Federation Internationale Des Ingenieurs Conseils

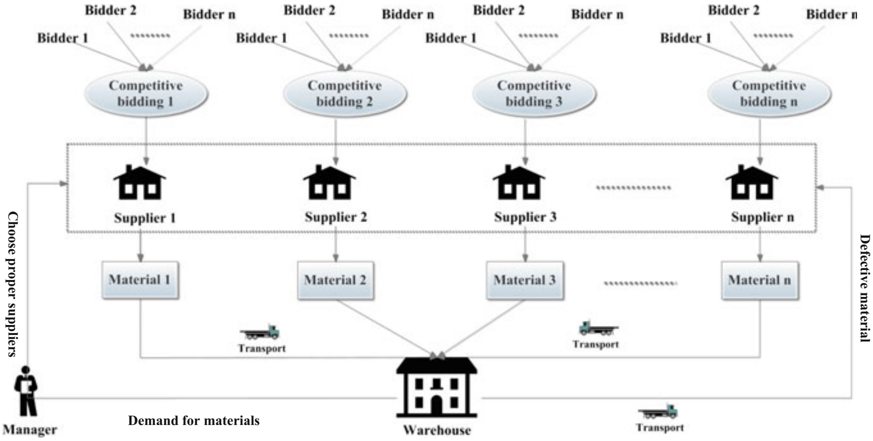


Fig. 26.1 The customer satisfaction level from hard to soft time windows

terms of the contract, the crucial materials in large-scale construction projects must be purchased through open tender, and it should be only one successful bidder for each material. At the second phase, manager purchase materials from the successful bidders. The materials are transported to a storage site in the storage area at the third phase. A general diagram of the classical purchasing issue is in Fig. 26.1. In practice, most construction projects have presented a new method to establish the purchase price. The new method is quite different from the traditional pricing way which only offers a fixed price list. A pricing formula for each material at each stage is involved in there. Since the prices of materials are changing over time during the whole construction duration, the new method is more beneficial to minimize total costs of the manager than the traditional way. At the same time, in order to ensure the quality of materials, the percentage of the main composition and impurity should be within the specified range. Since the construction project inventory shortage is not allowed, the total purchase quantity of the jth raw material must exceed the demanded quantity.

There are many uncertainties in the real world. In the process of procurement, the uncertainties are especially manifold. Thus, in order to approach actual situations, uncertainties must be considered in the JPCMPPMS. Though a lot of studies have considered uncertainty in the construction materials procurement problem, there are some uncertainties that have seldom been considered. For example, demand quantity of the jth raw material from the ith supplier is usually described using ambiguous linguistic statements, such as “it is about 5 ton” or “it is between 3 and 5 ton”. Random factors are also involved in the JPCMPPMS: because of special conditions such as the weather and the season, the demand quantities usually different. Another example is about the transportation price. For example, there are no precise data because of the fluctuating gasoline price. Furthermore, transportation distance may fluctuate between two building sites, depending on each driver’s path selection. That is to say, the demand quantity includes both fuzzy and random factors. Because of this, JPCMPPMS need to be studied in a fuzzy random environment. In addition, much of construction materials procurement problem have seldom considered using dynamic programming. However, in a large-scale construction project, it is often not economical to purchase all the construction materials at the same time at the beginning of the whole construction duration. Generally, the manager purchases construction materials in multiple stages. Thus, dynamic programming is applied in this paper and in the mathematical model. Another remarkable characteristic of this paper is inventory shortage penalty cost is taken into consideration. Much of the past research has seldom consider penalty cost. However, in order to guarantee normal construction operation, inventory shortage is not allowed. Therefore, punishment cost should be considered in procurement.

26.2.2 Model Formulation

(1) Pricing Formula
In JPCMPPMS, there are several versions of pricing formula which are usually used in practice. In this paper, the most popular version of pricing formula that is widely used in construction projects is considered.

$$p(x_{ij}) = \begin{cases} \beta_j(1+\alpha_j)^M, & \sum_{i=1}^{I} x_{ij} Z_i < A, \\ \delta_j \beta_j (1+\alpha_j)^M, & \sum_{i=1}^{I} x_{ij} Z_i > A, \end{cases} \tag{26.1}$$

where α_j is the rise and fall rate for the price of material j. If $\alpha_j > 0$, then it means that the price of material j will rise in the whole construction duration. If $\alpha_j < 0$, means the price of material j will fall in the whole construction duration. β_j is the spot price of material j in the first stage, then the price of material j in the $(M+1)_{th}$ stage should be $\beta_j(1+\alpha_j)^M$. However, the purchase quantity of construction materials in large scale construction projects is usually huge, so it is not fair to use the linear purchase cost, if the managers want some quantity discount when purchasing materials from suppliers. So, if the purchase quantity of material j is exceed a certain level, a price discount contract is used in this paper. δ_j is the discount percentage of maximum purchase quantity of material j. A is prescribed in the contract by the manager and supplier.

(2) Global Model
The joint pricing construction materials procurement problem with multiple suppliers (JPCMPPMS) is proposed in this paper. The leader's objective is to minimize project cost and maximize profit within certain constrains. Thus, based on the

above, a mathematical formulation for the construction material procurement in fuzzy random environment JPCMPPMS as follows:

$$
\begin{aligned}
\min_{x_{ij}} M = & \sum_{i=1}^{I} \sum_{j=1}^{J} p_{ij} x_{ij} \\
& + \sum_{i=1}^{N} \left[Z_i \left(\tilde{\bar{b}}_i s_i \sum_{j=1}^{J} x_{ij} + b_{io} \right) \right] + \sum_{i=1}^{N} \left[Z_i \left(h(T - t_i - t_{io}) \sum_{j=1}^{J} x_{ij} \right) \right] \\
& + \sum_{i=1}^{N} f_i Z_i + \sum_{i=1}^{I} \sum_{j=1}^{J} \xi_j \left(- \min \left\{ 0, \sum_{i=1}^{I} \sum_{j=1}^{J} x_{ij} - \tilde{\bar{U}}_j - I_j^{\min} \right\} \right)
\end{aligned}
\tag{26.2}
$$

$$
s.t. \quad O^{Q^{\min}} \leq x_{ij} \leq O^{Q^{\max}} \tag{26.3}
$$

$$
\sum_{j=1}^{J} x_{ij} \geq 0 \tag{26.4}
$$

$$
I_j^M \leq I_j^{\max} \tag{26.5}
$$

$$
\sum_{i=1}^{N} \sum_{j=1}^{J} x_{ij} Q_{ij} \geq q^* \tag{26.6}
$$

$$
\sum_{i=1}^{I} x_{ij} \geq \tilde{\bar{U}}_j \tag{26.7}
$$

$$
\frac{\sum_{i=1}^{N} \sum_{j=1}^{J} x_{ij} I_{kij}}{\sum_{i=1}^{N} \sum_{j=1}^{J} x_{ij}} \leq I_k^* \tag{26.8}
$$

$$
\frac{\sum_{i=1}^{N} \sum_{j=1}^{J} x_{ij} Q_{ij}}{\sum_{i=1}^{N} \sum_{j=1}^{J} x_{ij}} \geq Q^* \tag{26.9}
$$

$$
I_j^{M+1} = i_j^M + \sum_{i=1}^{N} x_{ij} - \tilde{\bar{U}}_j^M . \tag{26.10}
$$

In general, objective Eq. (26.1) represents the objective functions, and the objective of the decision makers is try to minimize total procurement costs in the procurement activities. It contains the cost of raw material procurement merchandise cost, order execution cost, fixed transportation cost, variable transportation cost and penalty cost. Considering the supplier production line's plumpness, each time the purchase quantity of the jth raw material from the ith supplier should be less than or equal to the maximum purchase quantity of the jth raw material from the ith supplier. At the same time, the amount should also be less than or equal to the minimum purchase quantity of the jth raw material from the ith supplier. The constraint is expressed in Eqs. (26.3) and (26.4). Equation (26.5) represents the inventory level of every raw material in every stage should not exceed the maximum inventory level for each material. Main composition of total raw material purchased have a total quantity limit as Eq. (26.6) shows. Equation (26.7) shows the total quantity of procurement should meet the demand at lest. Equations (26.8) and (26.9) represent it is necessary to provision the percentage of the main composition and impurity. Equation (26.10) represents the state equation.

26.3 Algorithm: DP-Based Genetic Algorithm

Genetic algorithms (GA) are known as a stochastic solution search procedure, which may be used to solve optimization problems using the concept of evolutionary computation imitating the Darwinian natural selection and biological reproduction of animal species [6]. GA deal with a cluster of alternate solutions called a population [3]. According to the Darwinian principle of "survival of the fittest", if GA suitably encoded, the GA obtains the optimal solution after a series of iterative computations. Prior to the application of GA, an encoding for the problem must be devised, and the size of the population depends on the size and the complexity of the problem. A fitness function, in which chromosomes in the population are evaluated, is also required. During the run, the chromosome evolves through a crossover operator and a mutation operator to generate offspring. In contrast to previous studies, the initialization, crossover and the mutation operators in the DP-based GA proposed here are designed based on the principle of dynamic programming (Fig. 26.2).

We describe the algorithm as the following procedure:

Step 1. Generate initial population $v_k(k = 1, 2, \ldots, \text{popsize})$ with n genes randomly.

Step 2. Initial evaluation: evaluate all chromosomes v_k, $(k = 1, 2, 3, \ldots, \text{popsize})$ and calculate their fitness values. The fitness values are associated with the values of objective function, so, the fitness function is as follows: $\text{eval}(v_k) = \begin{cases} C_{\max} - f(v_k) & f(v_k) < C_{\max} \\ 0 & f(v_k) \geq C_{\max}, \end{cases}$ where $C_{\max}$ is a number that is large enough to ensure the fitness function is decreasing and non-negative.

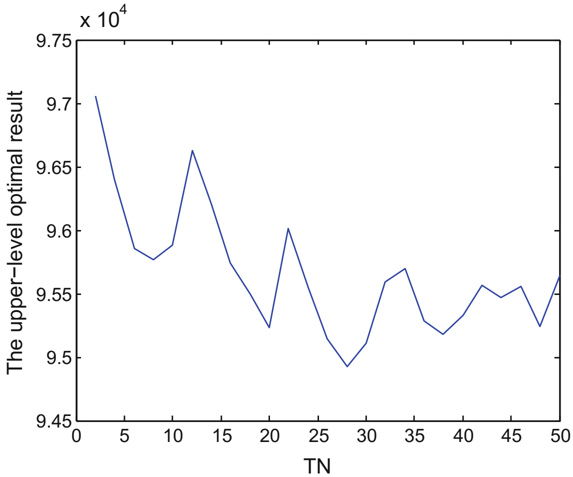


Fig. 26.2 The procedure of the proposed GA algorithm

Step 2.1. Ranking each chromosome according to its fitness value.
Step 2.2. Take the fist L chromosome from the top and denoted them as an overachiever collection $J(l)$, for $l = 1, 2, 3, \ldots, L$.

Step 3. Select the chromosomes for a new population. The selection process is based on spinning the roulette wheel characterized by the fitness of all chromosomes for popsize times, and each time we select a single chromosome. Thus we obtain popsize copies of chromosomes, denoted also by v_k, $(k = 1, 2, 3, \ldots, \text{popsize})$. Select probability $P_s = \frac{\text{eval}(v_k)}{\sum_{k=1}^{K} \text{eval}(v_k)}$

Step 4. The crossover operator is used to a selected pair of parents generating offspring. Generating a random real number μ from the interval [0, 1], the chromosome v_i will be chosen as a parent so long as $\mu < P_c$, where the parameter P_c is the probability of crossover. Then the selected parents $v_1', v_2', v_3', \ldots,$ are grouped to the pairs $(v_1' v_2'), (v_3' v_4'), \ldots$. Without loss of universality, the crossover operator is illustrated on each pair.

$$P_c = \begin{cases} \frac{k_1 \text{eval}(v_k)_{\max} - \text{eval}(v_k)'}{\text{eval}(v_k)_{\max} - \overline{\text{eval}}(v_k)}, & \text{eval}(v_k)' \geq \overline{\text{eval}}(v_k), \\ k_2, & \text{eval}(v_k)' < \overline{\text{eval}}(v_k), \end{cases}$$

where $\overline{\text{eval}}(v_k)$ is the average fitness value of all population, $\text{eval}(v_k)_{\max}$ is the maximum fitness value, $\text{eval}(v_k)'$ is the bigger fitness value among the two cross chromosomes, $\text{eval}(v_k)$ is the fitness value of the variation chromosome, k_1, k_2 is figure between 0 and 1.

Step 5. The mutation operator is used to update the chromosomes. In the same way, the following steps is repeated from $i = 1$ to popsize. Generating a random real number μ from the interval [0, 1], the chromosome X_i will be choose as a parent so long as $\mu < P_m$, where the parameter P_m is the probability of mutation. The mutation is executed by changing a randomly choose gene in the genetic code (0-1,1-0).

$$P_m = \begin{cases} \frac{\widetilde{C}[\text{eval}(v_k)'] k_3 (\text{eval}(v_k)_{\max} - \text{eval}(v_k)')}{\text{eval}(v_k)_{\max} - \overline{\text{eval}}(v_k)}, & \text{eval}(v_k)' \geq \overline{\text{eval}}(v_k), \\ k_4, & \text{eval}(v_k)' < \overline{\text{eval}}(v_k), \end{cases}$$

where

$$\widetilde{C}[\text{eval}(v_k)'] = \frac{\sum_{i=1}^{\text{offsize}} |\text{eval}(v_k)' - \text{eval}(v_k)|}{(\text{offsize} - 1) \max[|\text{eval}(v_k)' - \text{eval}(v_k)|]}$$

Step 6. Evaluation: compute the fitness of all chromosomes v_k, $(k = 1, 2, 3, \ldots, \text{popsize})$.

Step 7. Update $J(l)$, if the fitness value of the individuals in the population is bigger than the individuals in the overachiever collection, then, replace the individuals in the overachiever collection with the individuals in the population.

Step 8. If the stopping criterion is met, stop; otherwise, $t = t + 1$ and return to step 3.

26.4 Conclusions

In this paper, a fuzzy random dynamic programming model is developed for construction materials procurement problem in large-scale construction projects. For this problem, a new mathematical model was proposed, in which every kind of cost is fully considered and dynamic programming is also considered. Furthermore, an effective dynamic programming-based iterative algorithm that employs the genetic algorithm (GA) technique is developed to search for an efficient solution to the formulated mathematical model. The contribution of our proposed model is to enhance the fixed price procurement to the joint pricing-procurement. Although the fuzzy random dynamic programming model and DP-based GA algorithm discussed in this paper are helpful in solving some real world problems, detailed analysis and further research is necessary to reveal further properties.

Acknowledgments This research was supported by NSFC (Grant No. 71401020), NPOPSS (Grant No. 14BGL055), HPOPSS (Grant No. HB15GL111) and Human Social Science for Universities of Hebei (Grant No. SD151011, Grant No. BJ2016057).

References

1. Chen X, Cen L, Cen Y (2009) A raw material purchasing decision-making model of order allocation with multiple suppliers and its optimization. In: 2009 1st international conference on information science and engineering (ICISE), IEEE, pp 66–69
2. Da Silva GC, Bahiense L et al (2012) The dynamic space allocation problem: applying hybrid grasp and tabu search metaheuristics. Comput Oper Res 39(3):671–677
3. Gonçalves JF, Mendes JdM, Resende MG (2008) A genetic algorithm for the resource constrained multi-project scheduling problem. Eur J Oper Res 189(3):1171–1190
4. Ho S, Lin H et al (2008) OPSO: Orthogonal particle swarm optimization and its application to task assignment problems. IEEE Trans Syst, Man Cybern, Part A: Syst Hum 38(2):288–298
5. Hu X, Ding W (2010) The research of procurement strategies for the chinese herbal medicine enterprise. In: 2010 IEEE 17Th international conference on industrial engineering and engineering management (IE&EM), IEEE, pp 1443–1447
6. Min H, Ko HJ, Ko CS (2006) A genetic algorithm approach to developing the multi-echelon reverse logistics network for product returns. Omega 34(1):56–69
7. Tommelein ID (1998) Pull-driven scheduling for pipe-spool installation: simulation of lean construction technique. J Constr Eng Manag 124(4):279–288
8. Xu J, Zhou X (2009) A class of multi-objective expected value decision-making model with birandom coefficients and its application to flow shop scheduling problem. Inf Sci 179(17):2997–3017

Chapter 27
Research on the Enterprise Safety and Low-Carbon Behaviors Management and Application Based on the Evolutionary Game

Tao Zheng, Wenke Wang, Weiqian Dong, Bin Yan and Jinghua Gou

Abstract The interaction behavior between supervision department and workers in enterprise safety and low-carbon management is analyzed based on evolutionary game theory. An evolutionary game model of the enterprise safety and low-carbon supervision is established. The replicated dynamic equation and the dynamic evolution process of the both gaming parties are analyzed. The behavior features of the two gaming parties and the effect to the stability status are revealed the different kinds of evolutionary stability strategies are analyzed and the long-time stable tendency of enterprise safety and low-carbon supervision and worker's violation is predicted. Besides, the parameters' influences to evolutionary stability strategies are analyzed and the article provides empirical studies which prove that the model is more effective and verifies the validity of the model. Article concludes with some policy recommendations. For enterprises and workers safety and low-carbon management, the theoretical and methodological useful guide is provided.

Keywords Enterprise safety and low-carbon management · Worker's violation · Game · Duplicative dynamic · Evolutionary stable strategy

T. Zheng
School of Economics, Sichuan University, Chengdu 610065, People's Republic of China

T. Zheng
Scientific Research Department, Sichuan Normal University, Chengdu 610068, People's Republic of China

W. Wang (✉)
Visual Computing and Virtual Reality Key Laboratory of Sichuan Province, Sichuan Normal University, Chengdu 610068, People's Republic of China
e-mail: 510693393@qq.com; finance51@126.com

W. Wang · W. Dong · B. Yan · J. Gou
Business School, Sichuan Normal University, Chengdu 610101, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_27

27.1 Introduction

Enterprise safety and low-carbon production is an important guarantee for the sustainable development of enterprises. Worker safety and low-carbon production is not only related to the healthy growth of enterprises, but also the basic requirements for the health and safety of workers. Enterprises have an important responsibility for ensuring worker safety and low-carbon production and carrying out effective supervision on the safety and low-carbon production [9]. In recent years, the safety and low-carbon production in our country has improved a lot through the efforts of the government and enterprises, however, there are still the problems of frequent safety accidents and larger casualties. For enterprises, effective safety and low-carbon management, effective supervision of worker safety and low-carbon production are the prerequisites for enterprises to achieve safe and low-carbon production, and it is also an important guarantee for enterprises to realize economic, social and sustainable development. However, due to the monitoring cost of enterprises, a lack of efficiency, enterprise supervision and many other reasons, which leads enterprises often to pursue economic benefits but neglect safety and low-carbon production. Nowadays, the phenomenon of illegal production still occurred because employees excessively pursue high yield, high efficiency and reward, so it is difficult to guarantee the development of safety and low-carbon production for enterprises. For all the reasons above, in addition, the current regulatory implementation does not fully consider the reasons for the limited rationality of monitors and workers, which makes the occurrence of a lack of supervision of enterprise safety and low carbon production and inadequate supervision. How to effectively implement supervision, effectively guide and motivate workers to carry out safety and low-carbon production has become an imperative question. Cheng's [5] research indicated that the response plan of Miners' unsafe behavior results in the generation of unsafe behavior. In coal mining enterprises, coal mine safety supervision of the miners' unsafe behavior is a special nonlinear of secondary adjusting regulation, so coal mining enterprises should implement flexible safety supervision strategies. Therefore, the complexity of the enterprise has increased the difficulty of safety supervision. Zend and Lu [13] analyzed the safety and low-carbon behavior of farmers, leading enterprises, governments, consumers and other major stakeholders in the agricultural industry based on evolutionary game theory, and proposed financial subsidies, the establishment of the corresponding institutional arrangements, the government's full support and other policy recommendations.

Enterprise's own supervision, decision-making and interaction with workers will have an impact on the supervision of safety. Cavazza [3] thought that, so as to achieve safety production, enterprises need to pay more attention to the impacts on worker safety compliance because of social psychological factors and specific prevention programs. Reason [12] thought that risks and balance of interests are very important in safety production. Fogarty [6] analyzed the psychological background of worker's violation, and thought that the index of predicting worker's violation would help correct management attitude. The security theory based on behavior, which focuses on ABC model (Antecedent-Behavior-Consequence) has been a mainstream in the theoretical circles and practice of foreign countries [1]. However, in China, Liu [10] established a multilevel matter-element model for evaluating worker's safety quality based on the multilevel matter-element analysis method. Furthermore, the model is applied to the evaluation of worker's safety quality in a company. Liu and Liang [8] worked out the unsafe behavior intention scale based on Theory of Planned Behavior. They also made the formal scale of unsafe behavior intention and the exploratory factor structure model by demanding empirical evidence. Chen [4] established the enterprise security management model based on field management and carried out practical application research.

Unlike the direct supervision of unsafe high-carbon behavior, promoting the construction and effective evaluation of safety and low-carbon culture for enterprises is also an effective way to improve their safety levels. From the results of the analysis of the research on the safety and high-carbon behavior of coal mine workers in China, strengthening the emphasis on improving the organizational commitment level of coal mine workers, the sense of organizational support, and paying attention to the reasonable combination of the underground personnel and the people post matching will improve the safety level to a certain extent [2]. Combining the operation of all elements of the security management system and safety culture construction, not only can make the enterprise has a good safety culture, but also can reduce duplication of labor, so it can improve the safety awareness of enterprises at all levels, change their attitude towards safety and regulate worker's safety behavior [7]. At the same time, the effective evaluation of the level of enterprise safety culture can improve the construction of enterprise safety culture and adequately describe the role of safety culture in accident prevention [11].

The existing literature of worker's violation production is still relatively small and scattered, and a lot of research is concerned with the analysis of the factors that affect the safety of the enterprise and worker's violation, so there is only a little quantitative research. The research on the interaction of enterprise's supervision decisions and worker's behavior decision-making made that the internal mechanism of safety and low-carbon monitoring system is not enough. In addition, the current research mainly analyzes enterprise supervision departments and workers as complete rational objects, and it does not consider that enterprise supervision departments and workers mainly reflect limited rationality in the process of monitoring safety and low-carbon production. When dealing with the limited rational game, evolutionary game theory [14] can effectively cope with the evolution process of the both gaming parties, which based on the limited rationality, and then gradually imitate by the most beneficial strategy, eventually it reaches a equilibrium state [11] and draws up reliable conclusions which is closer to reality.

So this article makes use of evolutionary game theory to study on enterprise safety and low-carbon supervision. In the process of carrying out safety and low-carbon supervision, helping enterprises make more scientific and effective decision-making of safety low-carbon supervision and design better systems can effectively promote the implementation of enterprise safety and low-carbon production, which has great practical significance for safety and low-carbon production and enterprise's health, sustainable development.

27.2 Basic Hypothesis of Evolutionary Game Model of Enterprise Safety and Low-Carbon Supervision

For enterprise safety and low-carbon supervision, there is a game between enterprises and workers. As for safety and low-carbon production, enterprises can choose to monitor it or not, and the corresponding workers can choose safety and low-carbon production or illegal production. Because of different options of both sides, their strategies and benefits are asymmetric. The payment matrix is shown in Table 27.1.

From Table 27.1, we can know that the monitoring cost of worker safety and low-carbon production is I due to various constraints, enterprise monitoring departments can only implement supervision with probability x; In normal production, the enterprise obtains the comprehensive benefit R, and the normal benefit for workers is M. The probability of workers to carry out safe and low-carbon production is y, while the probability of illegal production is $1 - y$. It will not occur a safety accident if all workers carry out safety and low-carbon production. When workers carry out illegal operation, the illegal operation will improve production efficiency, and leads to the enterprise's reward for workers L. The worker's fine is F, if the enterprise checks out worker's violation operation. At this time, the probability of the occurrence of safety accidents by illegal operation is p, and the loss to workers after accidents is p, and the loss to the enterprise is Y. If the enterprise does not monitor worker's illegal operation, the probability of the occurrence of safety accidents would be q, and $q > p$. At this time, the loss to the enterprise is Y, and the social cost, environmental cost and penalty of the government supervision department is Z.

Table 27.1 Evolutionary game model of the enterprise safety and low-carbon supervision

Workers	Enterprise	
	Supervision X	No supervision $1 - X$
Safety low-carbon production y	M	M
	$R - I$	R
Illegal production $1 - y$	$M + L - F - pW$	$M + L - qW$
	$R - I + F - pY$	$R - q(Y + Z)$

27.3 Evolutionary Game Analysis of Enterprise Safety and Low-Carbon Production Supervision

The learning and dynamic adjustment speed of enterprise safety and low-carbon supervision strategy is not fast, so we can use its replicator dynamics to analyze the enterprise's interactive game of safety and low-carbon production when using evolutionary game analysis [7].

27.3.1 Evolutionary Game Replicator Dynamics and Stability Strategies of Worker's Illegal Production

From Table 27.1, the expected revenue of worker's safety and low-carbon production is

$$u_1 = xM + (1 - x)M = M. \tag{27.1}$$

The expected revenue of worker's illegal operation is

$$\begin{aligned} u_2 &= x(M + L - F - pW) + (1 - x)(M + L - qW) \\ &= M + L - qW + xqW - xpW - xF. \end{aligned} \tag{27.2}$$

So the average expected revenue of workers is

$$\bar{u} = yu_1 + (1 - y)u_2. \tag{27.3}$$

The replicated dynamic equation for worker's safety and low-carbon production is

$$F(y) = \frac{dy}{dt} = y(u_1 - \bar{u}) = y(1 - y)(qW - L - xqW + xpW + xF). \tag{27.4}$$

Let $F(y) = \frac{dy}{dt} = 0$, so the possible stability status is $y_1 = 0$, $y_2 = 1$,

$$x = \frac{qW - L}{qW - pW - F}. \tag{27.5}$$

From the nature of evolutionary stability strategies, when $F'(y^*) < 0$, y^* is the evolutionary stability strategy.

When $x = \frac{qW-L}{qW-pW-F}$, $F(y)$ is always 0. According to evolutionary game theory, when $x \neq \frac{qW-L}{qW-pW-F}$, the replicated dynamic equation has two equilibrium points $y_1 = 0$, $y_2 = 1$.

When $x > \frac{qW-L}{qW-pW-F}$, so $F'(0) < 0$, $y_1 = 0$ is the evolutionary stability strategy. After long-term repeated games, workers who have limited rationality would not to implement the safety and low-carbon production strategy. So enterprises would strengthen the supervision of worker's safety and low-carbon production.

When $x < \frac{qW-L}{qW-pW-F}$, $F'(0) < 0$, so $y_1 = 0$ is the evolutionary stability strategy. After long-term repeated games, enterprises which have limited rationality would not monitor safety and low-carbon production. In this case, enterprises will gradually reduce the emphasis on safety and low-carbon production, while workers choose to implement safe and low-carbon production.

27.3.2 The Evolutionary Game Replicated Dynamics and Stability Strategies of Enterprise Safety and Low-Carbon Supervision

From Table 27.1, the expected revenue of the implementation of safety and low-carbon supervision is

$$\begin{aligned} n_1 &= y(R-I) + (1-y)(R-I+F-pY) \\ &= R-I+F-pY-yF+ypY. \end{aligned} \tag{27.6}$$

While if enterprises do not implement safety and low-carbon supervision, the expected revenue is

$$\begin{aligned} n_2 &= yR + (1-y)[R-q(Y+Z)] \\ &= R-q(Y+Z)+yq(Y+Z). \end{aligned} \tag{27.7}$$

So the average expected revenue for the enterprise is

$$\bar{n} = xn_1 + (1-x)n_2. \tag{27.8}$$

So the replicated dynamic equation of the implementation of safety and low-carbon supervision is

$$\begin{aligned} H(x) &= \frac{dx}{dt} = x(n_1 - \bar{n}) \\ &= x(1-x)(F-pY+qY+qZ-I-yF+ypY-yqY-yqZ). \end{aligned} \tag{27.9}$$

Let $H(x) = \frac{dx}{dt} = 0$, so we can get the following stable status:

$$x_1 = 0, \quad x_2 = 1, \quad y = \frac{F - pY + qY + qZ - I}{F - pY + qY + qZ}. \tag{27.10}$$

From the nature of evolutionary stability strategies, when $H'(x^*) < 0$, so x^* is the evolutionary stability strategy.

When $y = \frac{F-pY+qY+qZ-I}{F-pY+qY+qZ}$, $H(x)$ is always 0. According to evolutionary game theory, when $y \neq \frac{F-pY+qY+qZ-I}{F-pY+qY+qZ}$, the replicated dynamic equation has two equilibrium points $x_1 = 0, x_2 = 1$.

When $y > \frac{F-pY+qY+qZ-I}{F-pY+qY+qZ}$, so $H'(0) < 0$, $x_1 = 0$ is the evolutionary stability strategy.

After a long-term evolution, the enterprise will not implement its safety and low-carbon supervision, while workers will implement safety and low-carbon production.

When $y < \frac{F-pY+qY+qZ-I}{F-pY+qY+qZ}$, so $H'(0) > 0$, $x_2 = 1$ is the evolutionary stability strategy. At this time, enterprises pay attention to safety and low-carbon production supervision, while workers do not implement safety and low-carbon production.

27.4 Game Analysis

Let $x^* = \frac{qW-L}{qW-pW-F}$, $y^* = \frac{F-pY+qY+qZ-I}{F-pY+qY+qZ}$.

We drew the replicated dynamic and game trends of safety and low-carbon production supervision for both enterprises and workers, as shown in Fig. 27.1.

From Fig. 27.1, in the game of safety and low-carbon production supervision between enterprises and workers, $x = 1, y = 0$ and $x = 0, y = 1$ are two evolutionary stability strategies of game. For safety and low-carbon supervision, the proportion of their respective strategies of enterprises and workers at the beginning determines the game development status of both gaming parties.

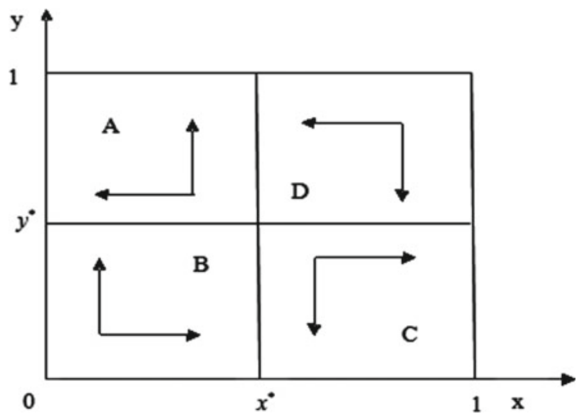


Fig. 27.1 Phase of enterprise safety and low-carbon supervision game

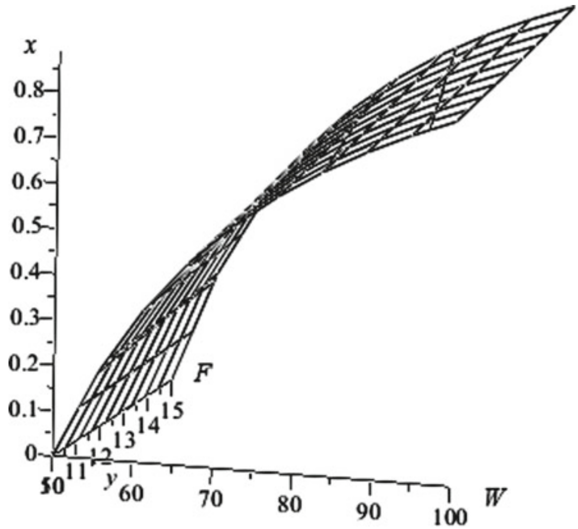


Fig. 27.2 Relation among x, F and W

When the initial situation of both sides is in the region A, the enterprise's supervision and the worker's supervision would converge to $x = 0$, $y = 1$, that is to say, workers will chose safety and low-carbon production, while enterprises do not implement safety and low-carbon supervision, so this is a perfect condition.

When the initial situation of both sides is in the region C, the enterprise's supervision and the worker's supervision would converge to $x = 0$, $y = 0$, that is to say, workers will choose illegal production, while enterprises will actively implement safety and low-carbon supervision.

(1) According to $x^* = \frac{qW-L}{qW-pW-F}$, take variables F and W, and draw its three-dimensional diagram, then we can know their relationship as shown in Fig. 27.2.

From Fig. 27.2, the probability of carrying out supervision x would increase with the fines F for workers by inspecting their illegal operation and the loss to workers after accidents. That is to say, the increase punishment of illegal production and the loss to workers after accidents W would increase the probability of enterprise supervision.

(2) According to $x^* = \frac{qW-L}{qW-pW-F}$, take variables L and W, and draw its three-dimensional diagram, then we can know their relationship as shown in Fig. 27.3.

From Fig. 27.3, the probability of carrying out supervision x would decrease with the increase of the reward for workers, because illegal operation improves production efficiency. The probability x would also increase with the loss to workers after accidents. That is also to say, The promotion of production efficiency may be caused by illegal production, although in fact the promotion of production efficiency would make enterprise supervision departments reduce supervision, however at this time enterprise supervision departments should increase the intensity of the safety and low-carbon supervision.

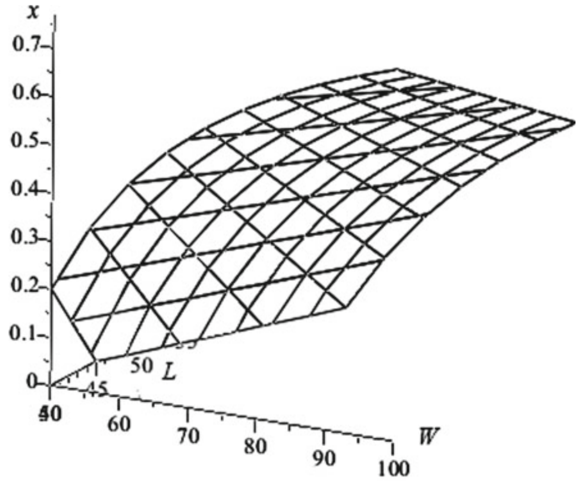


Fig. 27.3 Relation among x, F and W

(3) According to $y^* = \frac{F - pY + qY + qZ - I}{F - pY + qY + qZ}$, take variables F and I, and draw its three-dimensional diagram, then we can know their relationship as shown in Fig. 27.4.

From Fig. 27.4, with the increase of the monitoring cost of enterprise safety and low-carbon production I, the probability of workers to implement safety and low-carbon production will decrease correspondingly, and the increase of the fines of worker's illegal operation F will increase the probability of workers to implement safety and low-carbon production y. So enterprises should try to reduce the monitoring cost of safety and low-carbon production as far as possible in order to increase

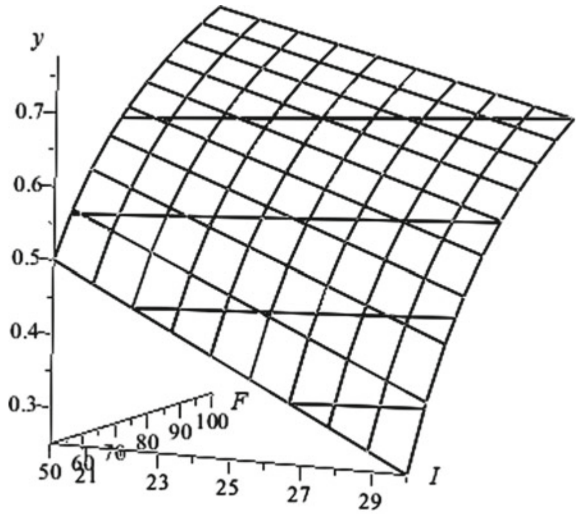


Fig. 27.4 Relation among y, F and I

the probability of worker's safety and low-carbon production. The increase of the fines for worker's illegal operation will lead to the implementation of safety and low-carbon production.

27.5 Example Analysis

A enterprise monitors worker's safety and low-carbon production, and the monitoring cost of worker's safety and low-carbon production is 600000 yuan. When workers implements illegal operation, because illegal operation improve production efficiency, the reward for workers is 400000 yuan. If the enterprise monitors illegal operation, the fine for workers is 100000 yuan. The probability of occurrence of a safety accident is 0.1, and the loss to workers after accidents is 800000 yuan, and the loss to the enterprise is 1200000 yuan. If the enterprise does not supervise worker's illegal operation, at this time the probability of occurrence of a safety accident is 0.8, and the social cost, the environment cost and penalty of the government supervision department is 800000 yuan.

According to Eq. (27.5), $x^* = \frac{qW-L}{qW-pW-F} = \frac{0.8\times 80-40}{0.8\times 80-0.1\times 80-10} = 0.52.$

According to Eq. (27.6), $y^* = \frac{F-pY+qY+qZ-I}{F-pY+qY+qZ} = 0.6.$

According to the analysis of the model, when the safety and low-carbon supervision intensity of the enterprise reaches $x = 0.52$, the initial proportion of worker's implementation of safety and low-carbon production and illegal production are both stable.For workers, when $y = 0.6$, the enterprise's supervision intensity keeps stable.

From the analysis of Fig. 27.1, when the enterprise's supervision intensity is less than $x = 0.52$, and the degree of workers to implement safety and low-carbon production is greater than $y = 0.6$, at this time both gaming parties will converge to the worker's implementation of safety and low-carbon production and the enterprise would not implement safety and low-carbon production, so this is a perfect condition.

When the enterprise's supervision intensity is greater than $x = 0.52$, and the degree of workers to implement safety and low-carbon production is less than $y = 0.6$, at this time both gaming parties will converge to worker's choice of illegal production and the enterprise actively implement safety and low-carbon supervision.

27.6 Conclusion

Effective supervision of enterprise safety and low-carbon production is an important guarantee for the sustainable development of enterprises. This article analyzed the interactive behavior of supervision departments and workers in the supervision of safety and low-carbon production and established the evolutionary game model of enterprise safety and low-carbon supervision. It also analyzed the replicated dynamic equation, the dynamic evolutionary process of both gaming parties, evolutionary stability strategies in different situations and predicted the long-term stable trend of enterprise safety and low-carbon supervision and worker's illegal production. Lastly this article also provided theoretical and methodological guidance for safety and low-carbon management of enterprises and workers. According to the results of this study, we can get the following conclusions and policy proposals:

(1) We can get two evolutionary stability strategies through the game analysis of enterprise safety and low-carbon supervision and worker's production, that is (violation, supervision) and (obedience, no supervision). In reality, most enterprises are in this situation: (violation, supervision). In the case, both enterprises and workers need to pay costs, so enterprises need to reconsider the rules of safety and low-carbon supervision and evolution law of both sides according to the game model, and design a more effective safety and low-carbon management mechanism, which would convert evolutionary strategies of both sides into (obedience, no supervision).

(2) The increasing monitoring cost of safety and low-carbon production supervision would decrease the probability of worker's safety and low-carbon production. So enterprise's supervision departments of safety and low-carbon production should continuously improve the supervision efficiency and reduce monitoring cost, including the cost of designing systems, operating cost of supervision departments and so on. Finally it will increase the probability of worker's safety and low-carbon production.

(3) The increasing penalties of worker's illegal production and the loss to workers after accidents will increase the probability and intensity of enterprise's supervision. The probability of enterprise's supervision would be decreased, because worker's illegal operations improves production efficiency which leads to the increasing reward for workers. The improvement of production efficiency is likely to be caused by illegal production, so enterprise's supervision departments should increase supervision, although in fact the improvement of production efficiency will make the enterprise's supervision department reduce supervision.

(4) From evolutionary strategies of enterprise's supervision and workers, we can know that reducing effects and impacts of worker's illegal production by punishment is limited. In the process of game evolution of enterprises and workers, the evolutionary result is affected by many factors. Enterprises can set up parameters of evolution model, then the evolution result will converge to (obedience, no supervision), and this evolution result is optimal for both enterprises and workers.

Acknowledgments Supported by the Philosophy and Social Sciences Program of Sichuan Province (No. SC15B071), Supported by the Program of the Visual Computing and Virtual Reality Key Laboratory of Sichuan Province (No.KJ201420), Supported by the Program of the Department of Education of Sichuan Province (No.14SB0022), Supported by the Sichuan provincial innovation and entrepreneurship students Training Program (201510636087).

References

1. Al-Hemoud AM, Al-Asfoor MM (2006) A behavior based safety approach at a Kuwait research institution. J Saf Res 37(2):201–206
2. Bo Q (2013) Current research situation and development direction of unsafe behaviours of mine employees in China. China Coal 6:034
3. Cavazza N, Serpe A (2009) Effects of safety climate on safety norm violations: exploring the mediating role of attitudinal ambivalence toward personal protective equipment. J Saf Res 40(4):277–283
4. Chen G, Wang LW, Fu L (2013) Methods and application of enterprise based on safety management site management. J Saf Sci Technol 9(4):180–185 (in Chinese)
5. Cheng L, Zhong WQ (2015) Research on mechanism through which safety supervision affects miners' unsafe behaviors. China Saf Sci J 25(1):16–22 (in Chinese)
6. Fogarty GJ, Shaw A (2010) Safety climate and the theory of planned behavior: towards the prediction of unsafe behavior. Accid Anal Prev 42(5):1455–1459
7. Gong YH, Zhang LB, Fan JC (2011) Discussion on the relationship between safety culture development and safety management system. J Saf Sci Technol 7(9):199–202 (in Chinese)
8. Hai-Bin L, Zhen-Dong L (2011) Study on influencing factors of unsafe behavioral intention. China Saf Sci J 21(8):15–21 (in Chinese)
9. Liu SX, Mei Q, Zhang ZZ (2012) On the evolution of workers safety compliance behavior in small and medium-size enterprises. J Syst Manag 21(2):275–282 (in Chinese)
10. Liu YY, Liu HQ, He CF (2012) Study on employee safety quality evaluation based on multilevel matter-element analysis. J Saf Sci Technol 8(12):184–189 (in Chinese)
11. Ma Y, Fu G, Zang YL (2014) Study on evaluation index system of enterprise safety culture construction level. China Saf Sci J 24(4):124–129 (in Chinese)
12. Reason J, Manstead A, Stradling S, Baxter J, Campbell K (1990) Errors and violations on the roads: a real distinction? Ergonomics 33(10–11):1315–1332
13. Zeng XY, Lu DY (2014) Game analysis of secure and low-carbon behavior of the key stakeholders in agricultural industrialization. Agric Econ 12:13–15 (in Chinese)
14. Zhang WY (2007) Game theory and information economics. Shanghai Sanlian Bookstore, Shanghai (in Chinese)

Chapter 28
Multivariable Analysis for Advanced Analytics of Wind Turbine Management

Alberto Pliego Marugán, Fausto Pedro García Márquez and Mayorkinos Papaelias

Abstract Operation and maintenance tasks on the wind turbines have an essential role to ensure the correct condition of the system and to minimize losses and increase the productivity. The condition monitoring systems installed on the main components of the wind turbines provide information about the tasks that should be carried out over the time. A novel statistical methodology for multivariable analysis of big data from wind turbines is presented in this paper. The objective is to analyse the necessary information from the condition monitoring systems installed in wind farms. The novel approach filters the main parameters from the collected signals and uses advanced computational techniques for evaluating the data and giving meaning to them. The main advantage of the approach is the possibility of the big data analysis based on the main information available.

Keywords Condition monitoring systems · Multivariable analysis · Wind turbine maintenance · Neural networks

28.1 Introduction

Nowadays, wind energy is the renewable energy source with the highest growth. Figure 28.1 shows the cumulative global capacity, that it has risen from 3.5 GW in 1994 to more than 420 GW in 2016. Therefore, the global capacity has grown by more than 10,000 percent after two decades. Moreover, the wind energy is estimated to increase at an annual average rate of 6 % until 2035 [22].

A.P. Marugán · F.P.G. Márquez (✉)
Ingenium Research Group, Universidad Castilla-La Mancha, 13071 Ciudad Real, Spain
e-mail: faustopedro.garcia@uclm.es

A.P. Marugán
e-mail: alberto.pliego@uclm.es

M. Papaelias
University of Birmingham, Birmingham, UK

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_28

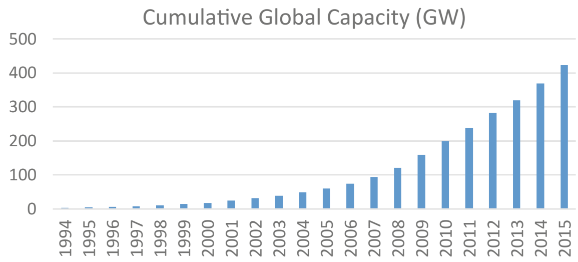


Fig. 28.1 Cumulative global capacity. *Source* Global Wind Energy Council [22]

The offshore wind farms are being the wind energy source with more importance. The main advantages of the offshore wind farms are [7]:

- The wind power captured by wind turbines (WTs) is more than onshore.
- The size of offshore wind farms can be larger than onshore.
- The environmental impact for offshore is less than in onshore.

  The principal disadvantages are:
- It is more complex to evaluate the wind feature.
- Larger investment costs. The offshore installation cost is 1.44 million €/MW, where the onshore is 0.78 million €/MW [12].
- Operation and maintenance (O&M) tasks are more complex and expensive than onshore. The offshore O&M costs are from 18 to 23 % of the total system costs, being 12 % for onshore wind farms [23].

The rapid growth of the wind energy generation and, specially, the fast expansion of the offshore windfarms, it is due to the new and larger wind turbines that present a more complex system. The use of Condition Monitoring Systems (CMSs) is becoming very useful to reduce the lost energy, the downtimes and the required outlays for O&M tasks [3]. There are several studies that prove the economic benefit of CMSs [16]. Different techniques and methods of condition monitoring (CM) are employed for detection and diagnosis of faults of WTs [6, 14, 17, 20]. Most of the research papers consider the CM in WTs referred to blades [24], gearboxes [10], electrical or electronic components [5] and tower [11]. CM leads to improve reliability, availability, maintainability, and safety (RAMS) to increase the productivity of wind farms [8, 19].

The first step of the CM process is the choice of an adequate technique for data acquisition, including electronic signals with the measurement of the required conditions, e.g., sound, vibration, voltage, temperature, speed [9]. Then, a correct signal processing method is applied, e.g. fast Fourier transform, wavelet transforms, hidden Markov models, statistical methods and trend analysis [11, 21]. In this paper a statistical methodology that can be used to improve the cost effectiveness of the CMSs is presented. The procedure is based on the idea that it is useful to collect the important information provided by the data and exclude the data that do not provide relevant information.

28.2 Methodology Proposed

As aforementioned, the methodology presented hereby is based in a statistical use of the data of different CMSs. There are different monitoring techniques, being the most employed: vibrations (vibration-based damage detection) using sensors such as piezoelectric accelerometers; oil analysis to determine viscosity and levels of contaminants; acoustic emission; motor current signature analysis [25]. The CMSs are aimed to provide a continuous monitoring of the condition of dynamic parts and power electronics of the wind turbines. The methodology proposed facilitates the determination of the condition of some components of the wind turbines using historical data and comparing them with the current information. The main assumption is that the wind turbine is working properly most of the time. The approach proposed in this paper, detailed in Sect. 28.2.1, gathers different feature parameters from certain parts of the received signal and carry out comparisons.

28.2.1 Gathering Feature Parameters from Signals

The CMS considered generates data each ten seconds every three hours. The amount of data is usually proportional to the accuracy of the analysis. However, the method is based on the idea that it is not necessary to storage the entire signal. This has the advantage of reducing the computational cost for analyzing the signals that can be received from a large number of CMS. Once the signals have been collected, the approach generated the main parameters that characterise the signals. The approach analyses big data, and therefore is it important to reduce the signal of thousands of samples to the main parameters, being the main:

- Average of the signal. This value can be useful when the signal has not a lot of abrupt changes. It can be used as a feature parameter for temperature or humidity signals.
- Energy (E) and power (W) of the signal. The expressions used to calculate such parameters are:

$$E = \sum_{n=-\infty}^{\infty} |x(n)|^2, \quad W = \lim_{N\to\infty} \frac{1}{2N+1} \sum_{n=-N}^{N} |x(n)|^2,$$

  where N is the total number of samples and $x\ (i)$ the data x for the sample i. This parameters can be very representative for electric signals or vibration signals.
- Maximum peaks of the signal. The maximum peaks of the signal represent the highest or the lowest amplitude reached by the signal. A peak can be very important in those signals that are almost constant all the time.
- Maximum peaks of the Fast Fourier Transform (FFT). The FFT represents the signal in the frequency domain. The maximum peaks are referred to the amplitude of the main frequency and the most important harmonics.

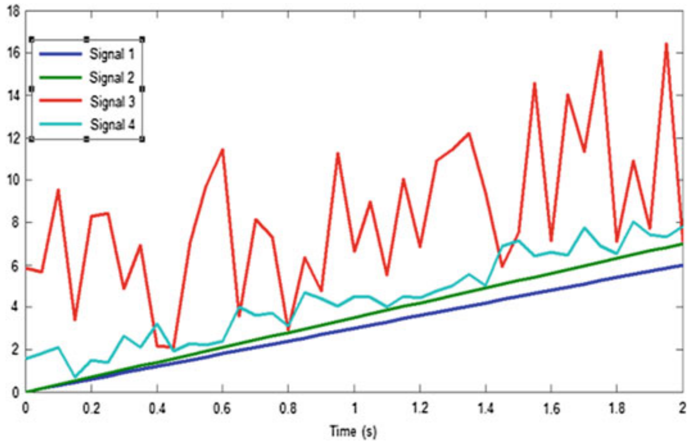


Fig. 28.2 Example for correlating signals

- Pearson correlation coefficient (r). The correlation coefficient between two discrete signals x and y can be expressed as:

$$r = \frac{N(\sum_{n=1}^{N} xy) - (\sum_{n=1}^{N} x)(\sum_{n=1}^{N} y)}{\sqrt{(N\sum_{n=1}^{N} x^2 - (\sum_{n=1}^{N} x)^2)(N\sum_{n=1}^{N} y^2 - (\sum_{n=1}^{N} y)^2)}}.$$

A case study is shown in Fig. 28.2 in order to clarify the calculation of the Pearson correlation coefficient for the collected signals, where 4 signals are considered. The date of each signal is different but the 4 signal are collected under the same conditions. Signal 1 (dark blue line) and 2 (green line) are increasing, whereas signals 3 (red line) and 4 (light blue) contain some noise. This function correlates the 4 signals placing the different correlation coefficients into a correlation matrix R as follows:

$$R = \begin{bmatrix} 1 & 1 & 0.52 & 0.96 \\ 1 & 1 & 0.52 & 0.96 \\ 0.52 & 0.52 & 1 & 0.43 \\ 0.96 & 0.96 & 0.43 & 1 \end{bmatrix}.$$

Each element r_{ij} of the matrix R contains the result of correlating the signals i and j. It is a symmetric matrix where the diagonal is filled with ones due to those elements represent the correlation of a signal with itself. The correlation between signals 1 and 2 is perfect because both are linear sequences. Table 28.1 shows the average of each column avoiding the 1 of the diagonal. This value will be used as a feature parameter of each signal.

Table 28.1 Average of correlation coefficients

	Signal 1	Signal 2	Signal 3	Signal 4
Correlation coefficient average	0.82	0.82	0.49	0.78

Table 28.1 shows that an abnormal behavior of the system could be due from the Signal 3 because the wind turbine is assumed to work properly most of the time. The possibility that a value can represent an abnormal condition of the system is because the different from the rest one value is bigger.

- Other time-domain feature parameters [4]. Other measurements can provide additional information of the signals, e.g. RMS, Standard Deviation, Skewness, Kurtosis, Crest Factor, Clearance Factor, Shape Indicator, Impulse Indicator, etc.

The approach therefore organizes chronologically the data and associates them with a certain condition of the system given by an alarm (Sect. 28.2.2).

28.2.2 Data Management

The approach does an ordination of all the data when the main parameters have been obtained from each signal. The data are chronologically ordered as shown in Table 28.2.

The element e^k_{ij} corresponds to the j parameter of the k signal collected at the time (date) i. The parameters placed in the same row should correspond to a signal collected at the same time.

The parameter are then associated with the corresponding condition of the system when every parameters have been ordered. The conditions of the wind turbine, given by the alarms, are collected for the period of time that are analysed the dataset. The case study considers a database from the European Project called OPTIMUS [18]. The main objective is to co-relate each row of the matrix to a specific condition of the wind turbine. Table 28.3 shows this correlation.

Table 28.2 shows the data (rows) and the associated condition of the WT. These conditions can be related to a normal state of the system, specific failures and different

Table 28.2 Chronological ordination of parameters

	Signal 1			Signal 2		
	Pearson corr. coef	Maximum FFT peak	Energy energy	Pearson corr. coef	Maximum FFT peak	Energy energy
Date 1	R^1_{11}	M^1_{12}	E^1_{13}	R^2_{11}	M^2_{12}	E^2_{13}
Date 2	R^1_{21}	M^1_{22}	E^1_{13}	R^2_{21}	M^2_{22}	E^2_{13}
Date 3	R^1_{31}	M^1_{32}	E^1_{13}	R^2_{31}	M^2_{32}	E^2_{13}
Date 4	R^1_{41}	M^1_{42}	E^1_{13}	R^2_{41}	M^2_{42}	E^2_{13}

Table 28.3 Association of data with condition of the WT

	Param. signal 1	Param. signal 2	Param. signal i	Condition of the WT
Date 1	e^1_{1j}	e^2_{1j}	e^k_{1j}	C1
Date 2	e^1_{2j}	e^2_{2j}	e^k_{2j}	C2
Date 3	e^1_{3j}	e^2_{3j}	e^k_{3j}	C3
Date 4	e^1_{4j}	e^2_{4j}	e^k_{4j}	C4

alarms. The main objective of this procedure is to establish a relationship between the main parameters extracted from the signal and the condition of the WT at a certain time. Considering the big data characteristics, e.g. there are thousands of signals and, therefore, millions of parameters, the analysis should be established employing statistical and heuristic methods. A novel pattern recognition through neural networks (NN) is employed in the approach.

28.2.3 Novel Pattern Recognition and Classification by Neural Network

In the former section, a way of manipulating and organizing data has been exposed. The purpose is to prepare the data to be subjected to a pattern recognition analysis. There are numerous models and procedures for pattern recognition analysis, i.e. statistical model, structural model, template matching model, NN based model, fuzzy based model, hybrid models, etc. [2, 13]. Each method has some advantages in function of the information available and the outcomes desired.

NN are used in problems that cannot be formulated as an exact method or an analytical solution. NN learns by itself and provides a good solution for the problem simulating the biological neurons in a reasonable time. An artificial NN consists of neurons that are simple processing units and weighted connections between those neurons [1]. The typical structure of a NN is showed in Fig. 28.3.

The variables presented in Fig. 28.3 are:

- Input layer: The nodes that forms the input layer are passive. They only duplicate the received value and propagate it through the multiple outputs.
- Hidden layer: The nodes of this layer are active because they modify the data in function of the weights.
- Output layer: The nodes of this layer are active due to they combine and modify the data in order to produce the k outputs of Fig. 28.3.
- or represents the strength of a connection (the connecting weight) between two neurons i and j, or between j and k.
- u or u nodes represents the simple processing units called neurons.

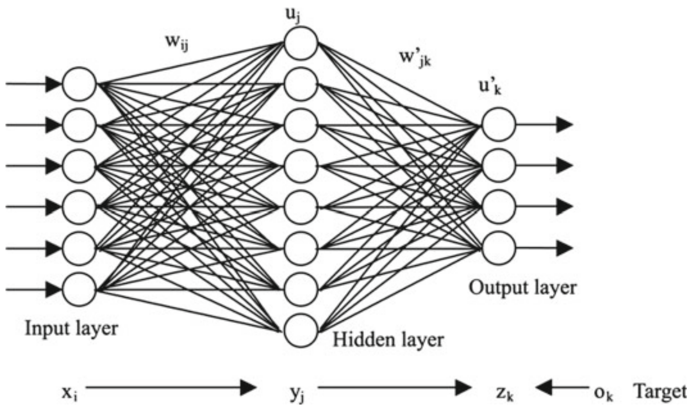


Fig. 28.3 Structure of an Artificial NN [23]

Basically, the NN receives a dataset and enter into a training process in order to recognise several patterns. The training process fits the different weights in order to provide the output. If the output is known, then the training is defined as supervised, otherwise, it is called unsupervised training. In this paper it is assumed that there is information available about the condition of the wind turbine all the time. The condition of the WT corresponds to the desired outputs of the NN, where the inputs are set in each row of the Table 28.2. The data used to design the NN is divided in the following groups:

- Training set: Around 75 % of the total amount of data.
- Validation set: Around 15 % of the total amount of data.
- Testing set: Around 15 % of the total amount of data.

The NN is expected to be able to learn from data and predict the output when a generic input is considered. The advantage of this model is that whatever the input, the NN will provide a predefined output.

28.3 Real Case Study

The data considered for this real case study is obtained from the European Project entitled OPTIMUS [18]. The datasets are come from the following CMSs installed in a WT:

- Vibration data from a Train Driver. The data available are signals of 1 second collected every three hours in 8 different points of the drive train from 01/04/2014 to 31/01/2015. Figure 28.4 shows the eight different regions of the drive train where vibration signals are collected. The signal will be identified regarding to this numeration, i.e. V1, V2 . . . V8.

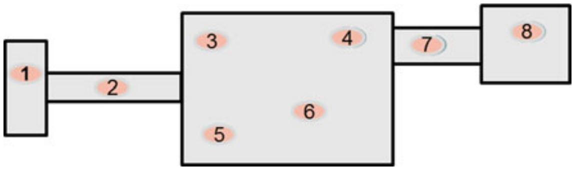


Fig. 28.4 Location of the different sensors in the train system of the WT

Table 28.4 Inputs and outputs for NN

	Input data			Output data		
	V1	V2	Vi	Alarm 1	Alarm 2	Alarm 3
Date 1	P_{1j}^{1}	P_{1j}^{2}	P_{1j}^{k}	1	0	0
Date 2	P_{2j}^{1}	P_{2j}^{2}	P_{2j}^{k}	0	0	0
Date 3	P_{3j}^{1}	P_{3j}^{2}	P_{3j}^{k}	0	1	0
Date 4	P_{4j}^{1}	P_{4j}^{2}	P_{4j}^{k}	0	0	1

The data available consists of a Report of Alarms generated by a SCADA registered from 01/10/2012 to 15/05/2015 where there are different types of alarms identified by a specific code. The codes are not indicated for reasons of confidentiality.

The vibration data from the Drive Train CM module has been considered and then it has been calculated the main parameter of the signal where they have been correlated by the FFTs.

The date of the alarms do not coincide with the data of the signals, therefore it has been associated the closest previous vibration data to each alarm.

The main parameters of the vibration data will be the input of the NN and the output will be defined in function of the number of alarms taken into account. In order to clarify this, Table 28.4 presents the data used for designing the NN.

The NNs have been designed attending to the geometric pyramid rule [15], i.e. the number of neurons of the hidden layer should be calculated by using the following expression:

$$h = \sqrt{m \times n},$$

where h is the number of neurons in the hidden layer, m is the number of neurons in the input layer and n is the number of neurons in the output layer.

In this case study, a total of three parameters of each signal Vi have been considered as inputs because the number of signal is 8. Therefore the number of neurons in the input layer is $8 \times 3 = 24$. Two different networks have been developed according to two kinds of outputs:

- NN1: The possible outputs are “Alarm generated or not generated”. The number of neurons in the hidden layer is 5.
- NN2: It has been determined that the possible outputs are Alarm 1, Alarm 2, Alarm 3 or none of them. The number of neurons in the hidden layer is 10.

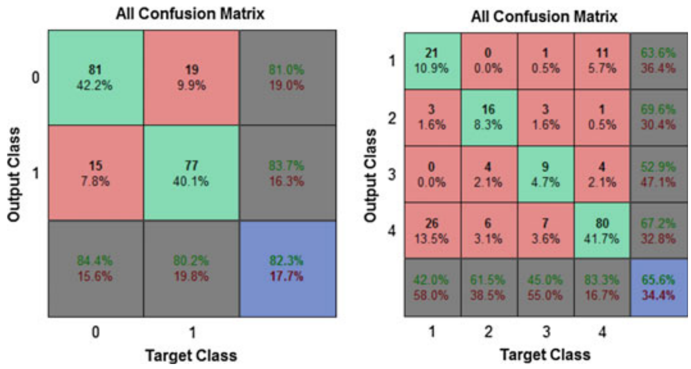


Fig. 28.5 Outcomes of the NN1 (*left*) and NN2 (*right*)

Figure 28.5 presents the outcomes of the NNs through two confusion matrixes. The confusion matrixes presented in Fig. 28.5 summarise the results from training, validation and test data process. A confusion matrix is a comparison between the desired result (target class) and the outcome provided by the NN (output class). The main objective is to maximise the value of the diagonal of the matrix.

The NN1 informs that it is possible to determine from the vibration data whether an alarm will occur or not with an accuracy of 82.3 %. The NN2 is able to distinguish the type of alarm with a success of 65.6 %.

28.4 Conclusions

This paper has presented a novel approach in order to analyse big data from condition monitoring systems and SCADA of a wind turbine. The methodology analyses the condition of the system. The main information of the data is obtained with the purpose of simplifying the analysis of the big data. The approach is based on three steps: To extract feature parameters; order, and; association of the data and pattern recognition. A real case study is presented in order to apply the procedure and demonstrate and validate the methodology. The data used hereby correspond to different condition monitoring systems installed in a wind turbine. Neural networks have been employed in order to analyse the main parameters gathered. Two different networks have been developed according to two kinds of outputs: NN1 the outputs are "Alarm generated or not generated"; NN2 considers Alarm 1, Alarm 2, Alarm 3 or none of them. The NN1 reports that it is possible to determine from the vibration data whether an alarm will occur or not with a high accuracy. The NN2 is able to distinguish the type of alarm with a medium accuracy.

Acknowledgments The work reported herewith has been financially supported by the Spanish Ministerio de Economíay Competitividad, under Research Grant DPI2015-67264, and the FP7 Research project with reference FP-7-Energy-2012-TREN-1:322430.

References

1. Arbib MA (2003) The handbook of brain theory and neural networks. MIT Press, Cambridge
2. Asht S, Dass R (2012) Pattern recognition techniques: a review. Int J Comput Sci Telecommun 3(8)
3. Azevedo HDM, Araújo AM, Bouchonneau N (2016) A review of wind turbine bearing condition monitoring: state of the art and challenges. Renew Sustain Energy Rev 56:368–379
4. Chen D, Wang W (2002) Classification of wavelet map patterns using multi-layer neural networks for gear fault detection. Mech Syst Signal Process 16(4):695–704
5. Chen Z, Guerrero JM, Blaabjerg F (2009) A review of the state of the art of power electronics for wind turbines. IEEE Trans Power Electron 24(8):1859–1875
6. de la Hermosa González RR, Márquez FPG et al (2015) Maintenance management of wind turbines structures via mfcs and wavelet transforms. Renew Sustain Energy Rev 48:472–482
7. Esteban MD, Diez JJ, López JS, Negro V (2011) Why offshore wind energy? Renew Energy 36(2):444–450
8. Gomez Munoz C, la Hermosa De et al (2014) A novel approach to fault detection and diagnosis on wind turbines. Glob Nest J 16(6):1029–1037
9. Gómez Muñoz CQ, García Márquez FP (2016) A new fault location approach for acoustic emission techniques in wind turbines. Energies 9(1):40
10. Guo P, Bai N (2011) Wind turbine gearbox condition monitoring with AAKR and moving window statistic methods. Energies 4(11):2077–2093
11. Jiang W, Fan Q, Gong J (2010) Optimization of welding joint between tower and bottom flange based on residual stress considerations in a wind turbine. Energy 35(1):461–467
12. Lloyd G (2007) Guideline for the certification of condition monitoring systems for wind turbines. Hamburg, Germany
13. Márquez FPG, Muñoz JMC (2012) A pattern recognition and data analysis method for maintenance management. Int J Syst Sci 43(6):1014–1028
14. Márquez FPG, Pérez JMP, Marugán AP, Papaelias M (2016) Identification of critical components of wind turbines using FTA over the time. Renew Energy 87:869–883
15. Masters T (1993) Practical neural network recipes in C++. Morgan Kaufmann, San Francisco
16. McMillan D, Ault GW (2007) Quantification of condition monitoring benefit for offshore wind turbines. Wind Eng 31(4):267–285
17. Novaes Pires de G, Alencar E, Kraj A (2010) Remote conditioning monitoring system for a hybrid wind diesel system-application at fernando de naronha island, brasil
18. OPTIMUS (2014) Demonstration of methods and tools for the optimisation of operational reliability of large-scale industrial wind turbines, optimus project
19. Papaelias M, Cheng L et al (2016) Inspection and structural health monitoring techniques for concentrated solar power plants. Renew Energy 85:1178–1191
20. Pliego Marugán A, García Márquez F (2014) System management for remote condition monitoring in railway systems. In: 6th IET conference on railway condition monitoring (RCM 2014), IET, pp 1–10
21. Pliego Marugán A, García Márquez FP, Pinar Pérez JM (2016) Optimal maintenance management of offshore wind farms. Energies 9(1):46
22. Pullen A (2015) Global wind report annual market update 2014. Technical report, Global Wind Report Annual Market, pp 3–9
23. Tavner P (2012) Offshore wind turbine reliability, availability and maintenance. Institution of Engineering and Technology, London
24. Tsai CS, Hsieh CT, Huang SJ (2006) Enhancement of damage-detection of wind turbine blades via cwt-based approaches. IEEE Trans Energy Convers 21(3):776–781
25. Wymore ML, Van Dam JE et al (2015) A survey of health monitoring systems for wind turbines. Renew Sustain Energy Rev 52:976–990

Chapter 29
Fuzzy Logic Controller to Control Voltage and Reactive Power Flow at the Network with Distribute Generation

Ahmadova Tamella Ahmad and Guliyev Huseyngulu Bayram

Abstract The structure and algorithm of the voltage and reactive power control system for distribution networks with on site power sources containing fuzzy logic controller (FLC) is presented. The controlling parameters are: the transformers voltage ratio and capacities of the reactive power sources Q_i in distribution networks. The placement of reactive power sources, their values and also transformers regulator's positions are determined using traditional methods of optimization for selected networks. The structure of reactive power sources and transformers voltage ratio control system containing the fuzzy logic controller is presented in this paper. The problem of optimal correction of transformers voltage ratio and power sources at time of their deviation from the preset values to minimize losses in studied network and maintaining of nodes voltages on the necessary level is considered. The algorithm of membership function formation for input variables of FLC to control/correct capacitors value is shown. Modeling results for real electrical circuit, Q correction in nodes and transformers impact on losses and voltage profile in studied network are presented.

Keywords Voltage and reactive power optimal control · Fuzzy logic · Optimal placement of static capacitor · Controller · Membership function

29.1 Introduction

For mode profitability conditions and voltage quality support in distributive electric networks the adjustable batteries of static capacitors and voltage control units for transformers under loading regulation are used.

A.T. Ahmad · G.H. Bayram (✉)
Azerbaijan Scientific-Research and Design-Prospecting Power Engineering Institute,
Sumgait State University, Sumqayit, Azerbaijan
e-mail: huseyngulu@mail.ru

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_29

Among voltage and reactive power regulating devices the automatic excitation regulators for local sources (synchronous generators, diesel or gas-turbine units) in distributed generation networks also are used.

The choice of a placement position and static condensers batteries rate planned for installation is the optimizing problem which essence consists of total active power losses minimization. Now methods of nonlinear optimization [3–5, 7, 16] and also heuristic methods are applied to the decision of the given problem [14].

With help of [3–5, 7, 14, 16] methods for planned schemes and predicted modes the batteries of static condensers optimum rates assumed for installation in network knots are defined. In real operation conditions the loadings consumption capacity in a network continuously changes, that leads to a deviation of a current production schedule from planned on the set period (days, weeks etc.). Actual values of reactive power in network knots will differ from optimum chosen values for their covering of condenser units capacities. The losses levels and knots voltages will change according to current mode changes in a network. Such current losses values and voltages will differ from their corresponding values in optimum modes.

The difference between current knot's reactive power value and optimum chosen capacity of the condenser battery is possible to compensate operatively by change of minimum share of capacity correction pre-setted in knot in a direction of losses reduction in a network.

The power factor correction condensers module usually consists of several separate elements or groups of elements, everyone with own contactor or switch. Reactive power covering demand and a power factor are continuously estimated and the condenser modules connected and disconnected necessarily for optimum level achievement. The algorithm of indistinct logic realized in block of current mode condition estimation in distributed generation (DG) network is developed for definition of optimum number of modules in each knot. In the same block the necessity of planned parameters values updating—rates of condensers capacities installed in controllable knots and transformer's voltage ratio is checked.

The problem solution on definition of necessity of connected condenser's capacity rate correction and a choice of transformer's voltage ratio is spent by developed indistinct system's algorithm in which as inputs the knots voltages and power losses indicators are defined. Thus necessity of condenser correction for this or that knot will be defined by an importance indicator of condenser's capacity variability. Necessity of correction of condenser's capacity for this or that knot is defined in case of large value of this indicator.

For practical correction of condenser's capacity value in knots of installation the indistinct logic regulator is used.

29.2 Structure of Reactive Power and Voltage Control System in Distributed Generation Networks

In dispatching management modern practice the operative modes correction in power system electric networks has a great value at control solutions acceptance at a network mode deviation on and from their values received on the base of optimum modes calculation. Thus for a choice of correcting actions for reactive power and voltage (RCV) management the criterion of a minimum of losses is used at performance of preservation conditions of the standard deviation of knots voltages [4, 10, 16–18]. RCV control in distribution networks basically is carried out by means of batteries of static condensers (BSC), and also generating sources, placing in a network for a local loads covering and transformers regulated under loading. The choice of adjustable static condensers batteries number and generating sources, their placing in network is an optimizing problem. The decision of given problem for electric network normal scheme defines the optimum number of regulating devices.

At an operational control in process of scheme and mode change current optimum values of voltage in knots $U_{i,\max}$ and total losses values in network $\Delta P_{i,\min}$ are defined. In accordance with calculated new values $U_{i,\max}$, $\Delta P_{i,\min}$ the setting of numbers of individual condensers $K_{KOH,i}$ for knots in which their installation is accepted, and transformers regulating devices positions $K_{t,i}$ are defined.

Such optimizing calculations can be executed in frame of the program complex for power system condition estimation. Algorithms used by these programs are known [1, 11, 12, 15, 19, 20] and basically consist in periodic optimizing calculations carrying out according to a current scheme condition and a system mode. On the basis of current optimizing calculations results comparison—knots voltages values and total losses in a network, with the optimum values established for base normal modes, necessity of condensers batteries capacities correction, transformers voltage ratio for remote adjustable transformers, voltages of generators placed in distributed generation system is defined. Depending on a deviation value of current optimum values of the voltage in controllable knots and network losses value from their corresponding values in nominal base mode the operating influences sizes for condenser batteries modules established in controllable knots switching on and positions of transformers regulating device are defined.

Following the above-stated distributed network reactive power control mode it is possible to present the general control scheme in form of the following block structure of the static condensers batteries, position of transformers switching and synchronous generators voltages co-ordinate control.

The general management concept for the purpose of optimum mode support in an electric network with the distributed generation consists in a choice of static condensers capacity from among the set condensers in knots, and also in transformer voltage ratio definition installed in connection point of DG network with a power system and its switching to position providing a minimum of power losses in a network. Necessity of correcting actions on condensers and the transformer arises at deviations of network current mode losses from their (planned) values calculated for network optimum modes.

In considered statement correcting control influence on change of condensers batteries modules in network knots and transformers voltage ratio accepted in form of linear dependence on a deviation of current conditions (changes of active and reactive power of knots loadings) [6]:

$$\Delta Y = f(k, \Delta d), \tag{29.1}$$

where $\Delta Y = \overline{Y} - Y$, $\Delta d = \overline{d} - d$, $\overline{Y}$ and $\overline{d}$ are the planned values of adjustable and initial data

$$\bar{Y} = \left\| \begin{matrix} C_{ki} \\ \cdot \\ K_{ti} \end{matrix} \right\|, \quad d = \left\| \begin{matrix} P_1 + jQ_1 \\ \cdot \\ P_i + jQ_i \end{matrix} \right\|, \qquad i = 1, \ldots, n$$

ΔY is operating influences on change of condenser capacity rate on $\Delta C_{k,i}$ and change of adjustable transformer's voltage ratio $\Delta K_{t,i}$;

Δd is initial data changes of knot loadings $\Delta P_i + j\Delta Q_i$.

Condensers and transformers control equation adjusting parameters are defined from optimization conditions:

$$\begin{aligned} &\min \ M\Delta P(\overline{Y} + f(k, \Delta d), x, d) \\ &k, \Delta P_i, \Delta Q_i, \end{aligned} \tag{29.2}$$

where x is dependent parameter:

$$x = \left\| \begin{matrix} U_1 \\ \cdot \\ \cdot \\ U_n \end{matrix} \right\|, \qquad i = 1, \ldots, n$$

knots voltages vector.

29.3 Correction of DG Network Mode Parameters by a Fuzzy Logic Method

The probabilistic and indistinct-defined character of scheme and network mode parameters variability (knots power and voltage) and also the electric systems modes (ESM) models nonlinearity, its parametrical uncertainty and unpredictability complicates application of the known determined methods for active and reactive power flows control in RG network. For the problem solution in choice of correcting control in [2, 8, 9, 12, 13, 15] the algorithms C as solving rules generated on the base of linear dependences in form of Eq. (29.1) are used. Besides, for correcting values for $C_{k,i}$ and $K_{t,j}$ an estimation of the determined active power losses equivalent is defined. But even in this case the problem becomes complicated when operating vector $\overline{Y}$ dimension increases.

In frame of indistinct system the correcting actions choice on sizes of knots capacities and transformers voltage ratio is formalized on base of linguistic rules defined by membership functions. The purpose of reactive power flow mode correction adds up to the "max–min" problem solution [10, 19].

For a problem of correcting action definition on change of $\mu_{S_C}(i)$ correction in i mode and at k accepted rules:

$$\mu_{S_C}(i) = \max k[\min[\mu_P(i), \mu_U(i)]], \tag{29.3}$$

where $\mu_P(i)$, $\mu_U(i)$ membership functions of power losses and voltage indicators.

From the determined optimizing problem solution with taking into account the forecast of initial data:

$$\overline{d} = \left|\overline{\pi}, \overline{P}_{H,i}, \overline{Q}_{H,i}\right|.$$

The planned targets for capacities rates in knots and values ratio of adjustable transformers are defined as:

$$\overline{Y} = \left|C_{k,1}, C_{k,2}, \ldots, C_{k,n}, K_{t,1}, K_{t,2}, \ldots, K_{t,m}\right|,$$

where, $\overline{\pi}$ is active power losses; $\overline{P}_{H,i}$, $\overline{Q}_{H,i}$ is predictably values of active both reactive power in the i^{th}loading knot.

In frame of the is indistinct-defined statement the problem solution of an estimation of a share of correcting action on condenser batteries rate change in knots and position of the transformers regulating devices, can be realized in the form of following stages:

(1) To define total active power losses for DG system base structure (are carried out on the base of flow distribution calculation programs). The program complex which provides steady stage calculations, and also calculations of Q sources optimum placement in a network is used in this research $\Delta C_{k,i}$.
(2) By change of a reactive power compensation share in each knot to carry out the flow distribution calculations and define the total active power losses in each case.
(3) To calculate losses decreasing indicators as:

$$\Pi_{\Delta P}(i) = \frac{(\Delta P(i) - \Delta P_{\min})}{(\Delta P_{\max} - \Delta P_{\min})}, \tag{29.4}$$

where $i = 2, 3, \ldots, n$ is number of knots in which batteries of condensers are placed. By indicator value Eq. (29.4) the capacity correction suitability for knot "i" is defined. If this indicator is highest for any i th knot the capacity correction in this knot is most comprehensible.

(4) The membership functions for power losses indicators $\mu(L_{\Delta P})$ and voltages in each knot $\mu_U(i)$ are accepted as model (29.3) inputs.
(5) Indistinct model's Eq. (29.3) target parameter—a resultant membership function $\mu_{S_c}(i)$ defines an acceptability of capacity correction in the given knot.

$$\widetilde{Y} = \widetilde{U} \circ \widetilde{\prod}_{\Delta P} \circ R(U, L_{\Delta P}, Y), \tag{29.5}$$

where $\ll \circ \gg$ is the "max–min" composition's symbol; R is the indistinct relation.
(6) Dephasification of an indistinct control output signal for $C_{k,i}$ condensers batteries capacity and transformers voltage ratio $K_{t,i}$ correction:

$$Y = F^{-1}\left[\widetilde{Y}\right], \tag{29.6}$$

where $\widetilde{Y}$= max {min [$\mu_P(i)$,$\mu_U(i)$]}, F is the phasing symbol.

According to the offered algorithm for network knot definition in which it would be preferable the battery of static condensers capacity correction, in the indistinct logic regulator the knots voltages and losses index (IL) $\Pi_{\Delta P}(i)$ calculated on Eq. (29.4) are accepted as input parameters. The higher limiting value for for knot is considered as the priority knot in which it is necessary to carry out the correction established in knot where the condensers battery was connected.

Indistinct variable of knots voltages, losses indexes $\Pi_{\Delta P}(i)$, and also an indicator of network knot preference in which the condensers battery will be corrected, are described in terms of indistinct definitions: Critical Low, Low, Low-Medium, Medium, High-edium and High.

Subsets fuzzy logic A_{1i} of an indicator of loss of capacity on terms to linguistic variables it is resulted below:

$$\begin{array}{lll}
A_{11} = CL & \text{(Critical Low)} & \underline{\underline{\Delta}}(p,\ \mu_{11}\ (p)), \\
A_{12} = L & \text{(Low)} & \underline{\underline{\Delta}}(p,\ \mu_{12}\ (p)), \\
A_{13} = LM & \text{(Low-Medium)} & \underline{\underline{\Delta}}(p,\ \mu_{13}\ (p)), \\
A_{14} = M & \text{(Medium)} & \underline{\underline{\Delta}}(p,\ \mu_{14}\ (p)), \\
A_{15} = HM & \text{(High-Medium)} & \underline{\underline{\Delta}}(p,\ \mu_{15}\ (p)), \\
A_{16} = H & \text{(High)} & \underline{\underline{\Delta}}(p,\ \mu_{16}\ (p)).
\end{array}$$

Defined A_1 a universum of a subset of fuzzy-ligic sets the generalised kind it is possible to write a below-mentioned variant

$$\underline{\underline{\Delta}}(p,\ \mu\ (p)) = \sum_{p \in A_1} \mu_{1i}(p_i))\big/p_i, \quad \forall p_i \in A_1$$

Subsets fuzzy logic A_{2j} of an indicator of voltage knots on terms to linguistic variables it is resulted analogically below:

$$
\begin{array}{lll}
A_{21} = CL & \text{(Critical Low)} & \underline{\underline{\Delta}}(V,\ \mu_{11}\ (V)) \\
A_{22} = L & \text{(Low)} & \underline{\underline{\Delta}}(V,\ \mu_{12}\ (V)), \\
A_{13} = LM & \text{(Low-Medium)} & \underline{\underline{\Delta}}(V,\ \mu_{13}\ (V)), \\
A_{24} = M & \text{(Medium)} & \underline{\underline{\Delta}}(V,\ \mu_{14}\ (V)), \\
A_{25} = HM & \text{(High-Medium)} & \underline{\underline{\Delta}}(V,\ \mu_{15}\ (V)), \\
A_{26} = H & \text{(High)} & \underline{\underline{\Delta}}(V,\ \mu_{16}\ (V)).
\end{array}
$$

But, defined A_2 a universum of a subset of fuzzy-ligic sets the generalised kind it is possible to write a below-mentioned variant

$$
\underline{\underline{\Delta}}\left(V,\ \mu_{2j}\ (V)\right) = \sum_{V \in A_2} \mu_{2j}(V_j)\big/V_j,\quad \forall V_j \in A_2
$$

In Tables 29.1 and 29.2 the membership functions for the above-stated indistinct linguistic variables are presented. For of network knot definition with the revealed preference of connected condensers battery's capacity correction it is necessary to

Table 29.1 The membership functions for losses and voltage indicators

Description of variables	Critical low	Low	Low-medium	Medium	High-medium	High
Indicators of capacity losses	<0.15	0–0.25	0.12–0.54	0.32–0.75	0.5–1.0	>0.75
Voltages	<0.92	0.9–0.94	0.91–0.96	0.95–1.0	0.98–1.05	1.02–1.1

Table 29.2 The membership functions of an indicator of correction preference (ICP) for condensers battery capacity in network knots

Variable	Critical low	Low	Low-medium	Medium	High-medium	High
ICP(i)	<0. 15	0–0.25	0.12–0.5	0.32–0.75	0.5–1.0	≥0.75

Table 29.3 Matrix of solutions for knot definition in which the condensers battery capacity correction is preferable

Parameters		Voltage in knots					
		CL	L	LM	M	HM	M
$L_{\Delta P}(i)$	CL	L	L	L	L	L	L
	L	L	L	L	L	LM	LM
	LM	L	L	L	LM	LM	M
	M	L	L	L	LM	M	HM
	HM	L	L	LM	M	HM	H
	H	L	LM	LM	M	HM	H

calculate the losses and voltage indicators for each knot, and then to present each of them as they own membership functions. Using the values of knot's voltages and losses indicators $L_{\Delta P}(i)$ the rules in form of the indistinct logic conclusions set matrix are formulated and generalized in Table 29.3: CL-Critical Low; L-Low; LM-Lw-Medium; M-Medium; HM-High-Medium; H-High;

29.4 The Results of Modeling

The application of indistinct regulator algorithm is reviewed on an example of one of IEEE 30 BUS electric network. Investigated network contains 30 kn. With use of ETAP program complex for the given network depending on knots loading the optimum points (network knots) for condensers batteries placing and their capacity rates are defined. The knots voltages, power factors, quantity and capacity of placed batteries, and also the total expenses necessary for condensers installation and operation are defined for three various loading modes. Calculations results are presented in Tables 29.4, 29.5, and 29.6.

Table 29.4 Calculation results of condensers batteries optimum distribution at 70 % loading

Knot name	Ucalc B %	cos(φ)	Information about BSC			Total cost (thousand $)
			kVAR/sect.	No of sect.	Total cap kVAR	
Bus1	100	0.858	1000	3	3000	122.4
Bus2	99.2	1	1000	3	3000	122.4
Bus3	99.2	0.997	1000	1	1000	41.6
Bus4	97.8	0.644	1000	3	3000	122.4
Bus5	97.6	0.999	1000	2	2000	82
Bus6	97	0.78	1000	3	3000	122.4
Bus7	97.3	1	1000	3	3000	122.4
Bus8	96.7	1	1000	3	3000	122.4
Bus9	96.9	0.998	1000	3	3000	122.4
Bus10	97.8	0.494	1000	3	3000	122.4
Bus11	96.5	1	1000	1	1000	41.6
Bus12	97.8	0.994	1000	3	3000	122.4
Bus13	96.3	0.997	1000	1	1000	41.6
Bus14	97.4	0.998	1000	3	3000	122.4
Bus15	96.1	0.968	1000	1	1000	41.6
Bus16	98.7	0.934	1000	2	2000	82
Bus17	101.7	0.9	1000	3	3000	122.4
Bus18	99.5	1	1000	2	2000	82
Bus19	98.1	0.992	1000	2	2000	82
In total	–	–	–	45	45000	1840.8

Table 29.5 Calculation results of condensers batteries optimum distribution at 85 % loading

Knot name	Ucalc B %	cos(φ)	Information about BSC			Total cost (thousand $)
			kVAR/sect.	No of sect.	Total cap kVAR	
Bus1	104.6	0.993	1000	3	3000	122.4
Bus2	104.3	0.941	1000	7	7000	284
Bus3	104.2	0.889				
Bus4	104.1	0.958	1000	4	4000	162.8
Bus5	103.5	0.999	1000	1	1000	41.6
Bus6	103.4	0.992	1000	6	6000	243.6
Bus7	103.7	1	1000	1	1000	41.6
Bus8	103.8	0.971	1000	9	9000	364.8
Bus9	103.9	1	1000	2	2000	82
Bus10	103.4	0.968	1000	1	1000	41.6
Bus11	103.2	0.999	1000	5	5000	203.2
Bus12	103.9	1	1000	1	1000	41.6
Bus13	101.9	0.914	1000	1	1000	41.6
Bus14	104.3	0.926	1000	5	5000	203.2
Bus15	102.5	0.999	1000	2	2000	82
Bus16	105.1	1	1000	11	11000	445.6
Bus17	105.5	0.91	1000	3	3000	122.4
Bus18	104.3	1	1000	2	2000	82
Bus19	104.7	0.935	1000	3	3000	122.4
In total	–	–	–	67	67000	2728.4

As evident from Table 29.4, at 70 % of network loading on 19 kn the 45 sections of condensers batteries should run, at loading of 85 % on 18 kn C the 67 should run and at last, at 100 % to network loading on 17 kn C the 102 sections should run. Thus total capacities of sections of the condenser accordingly make 45.0 MVar, 67.0 MVar and 102.0 MVar, and total expenses 1840.8; 2728.4 and 4141.2 thousand US dollars. I.e. at loading reduction the optimum capacity of sections running concerning to initial mode has decreased for 34.0 %, and for the third mode on 56.0 %.

On Fig. 29.1 the profiles of voltage levels for bus 10 V consumers of network district are shown at various modes. Apparently, in some knots the bus 10 V voltage has decreased on 5 % average. It has been defined, that voltage reduction on consumer buses up to permissible level is connected not with condenser batteries placing, but with discrepancy of distributive network lines length.

The above calculations results analysis shows that depending on electric network modes for increasing of electric power distribution efficiency, the periodical correction, i.e. optimum condensers batteries capacity control in knots is necessary.

Table 29.6 Calculation results of condensers batteries optimum distribution at 100 % loading

Knot name	Ucalc B %	cos(φ)	Information about BSC			Total cost (thousand $)
			kVAR/sect.	No of sect.	Total cap kVAR	
Bus1	104.7	0.904	1000	6	6000	243.6
Bus2	104	1	1000	3	3000	122.4
Bus3	104.1	0.958	1000	1	1000	41.6
Bus4	104	0.989	1000	6	6000	243.6
Bus5	103.8	0.984	1000	2	2000	82
Bus6	103.8	0.92	1000	10	10000	405.2
Bus7	103.9	1	1000	1	1000	41.6
Bus8	103.4	0.933	1000	6	6000	243.6
Bus9	103.6	1	1000	2	2000	82
Bus10	103.4	0.966	1000	1	1000	41.6
Bus11	103.5	0.948	1000	13	13000	526.4
Bus12	104.6	1	1000	1	1000	41.6
Bus13	102	0.836				
Bus14	105.8	0.925	1000	6	6000	243.6
Bus15	104	0.999	1000	3	3000	122.4
Bus16	106.2	1	1000	14	14000	566.8
Bus17	105.2	0.831				
Bus18	104.7	1	1000	14	14000	566.8
Bus19	104.4	0.958	1000	13	13000	526.4
In total	–	–	–	102	102000	4141.2

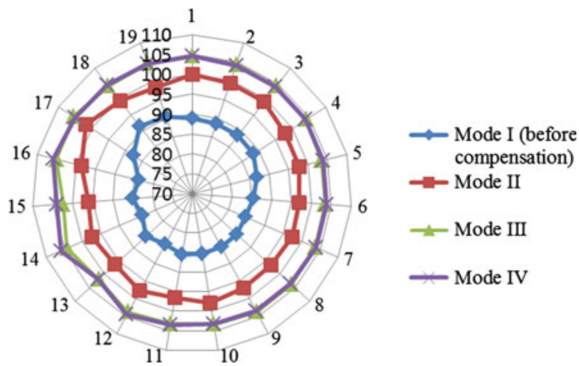


Fig. 29.1 Voltage profiles in 10 V kn

29.5 Conclusion

1. For optimum electric network mode correction the model of reactive power and voltages indistinct control is developed allowing improving the knots voltage values and reducing power losses.

2. An algorithm realizing the regulator indistinct logic principle is developed for condensers batteries capacity operative correction in knots by criterion of a network's mode optimality.

3. On the base of researches provided on an example of 30-kn IEEE network scheme, are established that the operative condensers batteries capacity correction on the by means of the indistinct logic regulator allows to keep optimum conditions for DG mode at current loading deviations on network buses.

References

1. Alonso M, Amaris H (2009) Voltage stability in distribution networks with dg. In: PowerTech, 2009 IEEE Bucharest. IEEE, pp 1–6
2. Aliyev R, Arabskiy (2014) Information systems for gas production processes. The state of the art and perspectives, p 462
3. Baran ME, Wu FF (1989) Optimal sizing of capacitors placed on a radial distribution system. IEEE Trans Power Deliv 4(1):735–743
4. Chiang ID, Wang JC et al (1995) Optimal capacitor placement, replacement and control in large-scale unbalanced distribution systems: modeling and a new formulation. IEEE Trans Power Syst 10(1):356–362
5. Chis M, Salama M, Jayaram S (1997) Capacitor placement in distribution systems using heuristic search strategies. In: IEE proceedings-generation, transmission and distribution, IET vol 144, pp 225–230
6. Gamm AZ, Kucherov YN, Palamarchuk SI (1990) Methods of the decision of problems of real time in electric power industry. Science, Novosibirsk, p 294 (in Russia)
7. Grainger JJ, Lee S (1981) Optimum size and location of shunt capacitors for reduction of losses on distribution feeders. IEEE Transa Power Appar Syst 3:1105–1118
8. Guliyev H, Farkhadov Z, Mammadov J (2015) System of automatic regulation of reactive power by means of fuzzy logic. Reliab Theory Appl 10(2):50–58
9. Hashimov AM, Guliyev HB, Rahmanov NR (2010) Improved fuzzy algorithm to control reactive capacity and voltage in distributive networks. Energetika, Minsk 2:29–39
10. Khalil TM, Youssef HK, Aziz MA (2007) Optimal capacitor placement on radial distribution feeders in presence of nonlinear loads using binary particle swarm optimization. In: 19th international conference on electricity distribution, vol 5, pp 1–4
11. Lin Y (2004) Systematic approach for the design of a fuzzy power system stabiliser. In: 2004 international conference on power system technology, 2004. PowerCon 2004. IEEE, vol 1, pp 747–752
12. Nayeripour M, Khorsand H et al (2010) A new approach based on fuzzy controller for volt/var control in distribution system. Aust J Basic Appl Sci 4(3):468–480
13. Rakhmanov NR, Guliyev HB (2015) Modelling process of capacity manufacture by wind power station at forecasting of the mode covering capacity of loading in the power supply system inside daily cycles. Problemi Energetiki (Problems of energy) 3:3–11
14. Salama M, Chikhani A (1993) A simplified network approach to the var control problem for radial distribution systems. IEEE Trans Power Deliv 8(3):1529–1535

15. Voytov ON, Voronin BT et al (1986) Automated system of operatively-dispatching control of electro power systems. Science, Novosibirsk, p 205 (in Russia)
16. Wu Z, Lo K (1995) Optimal choice of fixed and switched capacitors in radial distributors with distorted substation voltage. In: IEE proceedings-generation, transmission and distribution, IET, vol 142, pp 24–28
17. Yusifbayli N, Guliyev H (2011) Intelligent control system of voltage regimes in the electrical networks. In: IEEE PES innovative smart grid Europe, pp 5–7
18. Yusifbayli N, Guliyev H (2012) Intelligent voltage regulation on base of fuzzy sets theory. In: The 12th international conference on pobabillstic methods applied to power systems. PMAPS, pp 447–453
19. Zadeh LA (1973) Outline of a new approach to the analysis of complex systems and decision processes. IEEE Trans Syst Man Cybern 1:28–44
20. Zadeh LA (1984) Making computers think like people: the termfuzzy thinking? IEEE Spectr 21(8):26–32

Chapter 30
A Fuzzy Comprehensive Evaluation System Based Delphi–AHP and Its Application to R&D Planning Project Evaluation

Jun Gang and Ying Wei

Abstract Research and development (R&D) projects evaluation has received considerable attention, which is very important to scientific research management. In this paper, a fuzzy comprehensive evaluation system based on Delphi–AHP, which includes a group decision—making method to develop a hierarchical structure for R&D planning projects evaluation, an improved analytic hierarchy process based Delphi (Delphi–AHP) to determine the index weights, and a fuzzy comprehensive evaluation method to calculate the evaluation results, is proposed. Finally, a practical case from Sichuan Institute of Building Research is used to prove the efficiency both of the methods and evaluation system.

Keywords Analytic hierarchy process (AHP) · Delphi · R&D projects evaluation · Fuzzy comprehensive evaluation

30.1 Introduction

Private sector innovation and research and development (R&D) activities substantially contribute to sustainable growth [3], especially for the system—transformed institutes. Although research on R&D project evaluation has received considerable attention in the recent years, the relevant researches begun at the end of Twentieth Century in China. For the study of R&D project evaluation is vital to the management of scientific research, which can supervise and control scientific research effectively, as well as assist the scientific decision—making and a solid foundation to complete the research task, an effective mechanism to resolve this kind of conflict is necessary to screen R&D project scientifically.

R&D project is a complex decision-making process relating to many factors, such as economy, technology and market [1]. It has been proved that making full use of

J. Gang (✉) · Y. Wei
Sichuan Institute of Building Research, Chengdu 610065, People's Republic of China
e-mail: 467488122@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_30

expert experience combing quantitative and qualitative analysis is an effective way to improve the quality of project selection. Some published studies on R&D evaluation have developed a wide variety of models related to experts' judgments [8]. For example, Poh [6] paid attention to the effectiveness and suitability of the techniques, presenting a comparative study on a number of classes of R&D evaluation methods based on the AHP. This includes challenges to R&D planning project evaluation decisions.

In this paper, we try to build a fuzzy comprehensive evaluation system to solve the complex decision-making problem, which includes a group decision-making method to develop a hierarchical structure for R&D projects evaluation, an AHP based Delphi to determine the Index weights, and a fuzzy comprehensive evaluation method to calculate the evaluation results.

30.2 Problem Statement

With the increase of national, local and enterprise technology investment, the evaluation of R&D planning project, which as an important part of scientific and technological management has achieved more and more attention. Project evaluation actually plays a core role in the process of investment decision.

In order to evaluate R&D projects more scientifically, three main steps must be given more consideration. The choice of a good evaluation index system means half success of the project evaluation, while a bad index may lead decision makers dangerously astray. The second is to determine the weights of indexes. Although this problem has been studied by many scholars for a long time, it is still a difficult problem in the actual evaluation process for the combination of subjective and objective. The third is to develop scoring criteria and calculate the final evaluation results. In general, the experts either give objective scores to each project, or make subjective evaluation after comparison with each other.

So far, the evaluation of R&D planning project has been widely unfolded, but there are also many problems. Traditional research can not meet the requirements of research and development work under the new situation. Meanwhile, the study of the evaluation theory and method, especially combining scientific and technological development laws and policies is hard to get attention. Otherwise, in the current project evaluation method, expert assessment is used mostly. However, most of the indexes are qualitative and semi-quantitative indicators, which is hard to be scientific and rational by this method. And the assessment results are easily influenced by personal knowledge structure, personal preferences and other subjective factors. So the evaluation method is hysteretic relatively, which leads the evaluation results are hard to grade, reducing the applicability of the project in science and technology evaluation results.

30.3 Evaluation System

There are three important parts to a complete evaluation of R&D planning project, including build an index system, determine the weight and a comprehensive evaluation. In this section, to deal with the problems above, first, we highlight the drawbacks of both Delphi and AHP, which are traditional evaluation methods, and adopt a new hybrid Delphi–AHP method for a proper evaluation of decision criteria. Then, the steps of a fuzzy comprehensive evaluation are introduced.

30.3.1 Establish Index System Using Delphi

The Delphi technique is an expert opinion survey method with three basic characteristics [4], which is a well established means of collecting information and gaining consensus among experts on various factors or issues [7], and its most major advantage is individual and anonymity. In this paper, we use the Delphi technique to establish the index system, the process is described in Fig. 30.1.

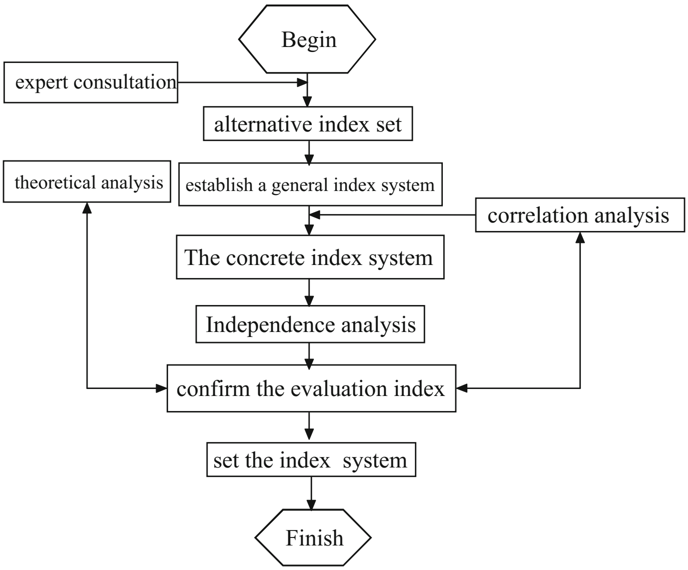


Fig. 30.1 Index screening process

30.3.2 Improved AHP Based on Delphi

Firstly, the experts give their opinions by whole questionnaire which wastes of time in a certain extent on the other hand. The Analytic hierarchy process (AHP) is a well-known technique used in multi-criteria decision making, providing the decision maker with relevant information to assist them in choosing the best alternative or to rank a set of alternatives. It can be applied to evaluate both qualitative and quantitative elements [2].

However, the traditional AHP has two fatal weaknesses which lead it cannot be used to calculate the weight of indexes. First, the traditional AHP use 1–9 scale to reflect the importance of indexes. Although it has good performance in scheme comparison and sequence, it may give results not in conformity with the actual in calculating weights. For example, there are two indexes A and B, and A is a little more important than B. Then A is 3 times more important than B, and the weights of A and B will be 0.75 and 0.25 respectively, which are obvious improper. Second, the traditional AHP does not consider the aggregation of multiple experts' views. In actual decision, we either use the average comparison matrix which leads to a weak consistency, or modify the matrix repeatedly which leads to a complex and fussy process.

Taking these disadvantages above into consideration, we make some improvements on the methods. First, we use a new scale from 1/9 to 9/9 which can reflect the actual weights better. The detailed information on the 1/9–9/9 scale is showed in Table 30.1. Second, we use the Delphi method to aggregation of multiple experts' views. Also, we replace the back-to-back communication mode as face-to-face meeting mode in Delphi, to improve the efficiency of decision making. Of course, the experts cannot exchange opinions with each other at the meeting. In this way, it still keeps the anonymity and improves the evaluation efficiency, meanwhile, feedback the grade of each index in time.

Table 30.1 A nine-point scale of AHP evaluation

Relative importance	Explanation
9/9	Compared with two goals, they have equal importance
9/7	one is a little important than the other
9/5	one is more important than the other
9/3	one is more important than the other obviously
9/1	one is more important than the other absolutely
9/8 9/6 9/4 9/2	strike an average among the adjacent value

30.3.3 Overall Steps of the Fuzzy Comprehensive System

After the index system are determined using Delphi method and the weight are calculated using an improved Delphi–AHP, a fuzzy comprehensive method is used to evaluate the candidate R&D projects, the overall procedures of the proposed comprehensive system are as follows.

Step 1 Build the analytic hierarchy structure, which divides the final goal into three levels like goal, aspect and detail objectives like.

Step 2 Construct the judgement matrices by the new scale. For each value in the matrix, every expert first scores by themselves, and then Delphi method is used to gather the experts' opinions, until get a consistent result.

Step 3 Calculate the weights of indexes $w = (w_1, w_2, \ldots, w_n)$. It can get the relevant importance weights to the upon level through the largest eigenvalue of judgment matrix.

① Every element of the judgment matrix multiply by m_{ij}, and

$$m_{ij} = \prod_{j-1}^{n} c_{ij}(i, j = 1, 2, 3, \ldots, n).$$

② Calculate the $n - th$ root $\overline{wi}$ of m_i, while

$$\overline{w_i} = \sqrt[n]{m_i}(i = 1, 2, 3, \ldots, n).$$

③ Normalization the vector quantity $\overline{w} = (\overline{w_1}, \overline{w_2}, \ldots, \overline{w_n})$, and $w = (w_1, w_2, \ldots, w_n)$ is the approximate solution of requested eigenvector,

$$\overline{w_i} = \frac{w_i}{\sum_{i-1}^{n} \overline{w_j}}.$$

④ Calculate the largest eigenvalue $\lambda_{\max}$,

$$\lambda_{\max} = \sum_{1}^{n} \frac{(CW)_i}{nw_i}.$$

Step 4 For each candidate project, experts give fuzzy evaluation to each index. The fuzzy linguistic set is (bad, common, good, very good).

Step 5 Calculate the fuzzy comprehensive evaluation results.

① Build fuzzy evaluation matrix R, where, $r_{ij} = \frac{n_{ij}}{N}$, $n_{ij} = w_{kv_{ijk}}$, and V_{ijk} is the vote of k^{th} expert for j^{th} fuzzy level of i^{th} index.

② Calculate the fuzzy result $B = wR = (B_1, B_2, B_3, B_4)$.

③ Judge the project evaluation result. If, then the project is eliminated, else calculate the final score using the following equation:

$$V = (B_1, B_2, B_3, B_4)I(25, 50, 75, 100).$$

30.4 Case Study

Sichuan Institute of Building Research (SIBR) always takes the scientific and technical innovation as the very foundation. As a state-owned wholly-owned science and technology enterprises in the first conversion, SIBR further strengthens the scientific research investment in manpower and material resources with the increasing of R&D planning projects. In order to improve the R&D planning project management, it is necessary to give a comprehensive and rational judgment on planning project by building an evaluation index system and evaluation model, which can provide some theories and methods on project assessment.

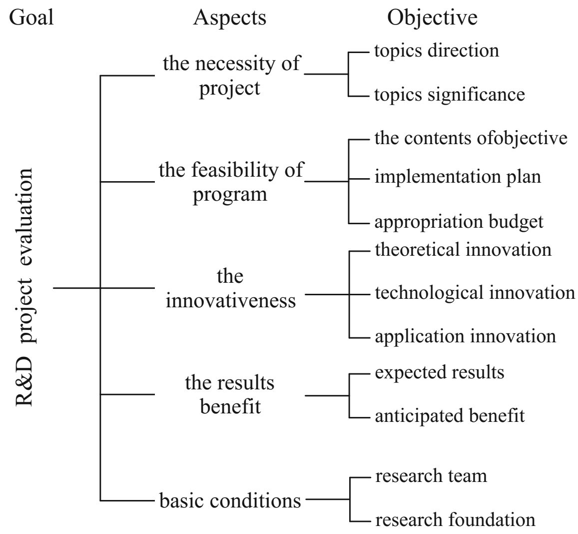
30.4.1 Building the Hierarchy Model

We first proposed over 12 criteria for R&D planning project evaluation based on reviewing relevant literature and the current evaluation approach. We initially developed a hierarchy evaluation model and asked experts to review it for the sake of feasible application in SIBR project evaluation. Ten experts with abundant experience on R&D planning projects were selected. We asked for an interview with the ten experts to review the initial hierarchy to discuss with the experts and immediately revise the hierarchy model directly if revise is needed. A description brochure of criteria was also given to them to check whether these descriptions or definitions of criteria in the hierarchy were understandable, helping the experts have a more in-depth understanding when determine the weight and judge the project.

After two rounds of expert investigation, we get a three-level indicator system containing a goal, five aspects and twelve objectives taking the physical truth of system transformed enterprise into consideration. After revising both the hierarchy and descriptions of criteria, we finally developed a hierarchy model (Fig. 30.2). Five aspects of the decision goal are as follows:

(1) The necessity of project: it investigates whether the project accords with the direction of national policy and industrial development, including topics direction and topics significance.
(2) The feasibility of program: it investigates whether the goal and method of the project is reasonable, and whether the content is clear, including the contents of objective, implementation plan and appropriation budget.

Fig. 30.2 The hierarchy model



(3) The innovativeness: it conforms to the demand of masses entrepreneurship and innovation, including theoretical, technological and application innovation.
(4) The results benefit: it mainly inspects the output of project, which is the embody of R&D planning project transferring to scientific and technological achievements, including expected results and anticipated benefit.
(5) Basic conditions: it mainly inspects the input of project, checking whether it has the relevant condition to carry out the project, including research team and foundation.

30.4.2 Fuzzy Weights of Evaluation Criteria

We interviewed ten experts from the technical advisory committee with more than ten years' project experience to evaluate the hierarchy model. We analyzed their subjective judgments for the hierarchy model by Expert Choice immediately after each question. If the subjective judgments of the experts were inconsistent, we asked them to repeat the pair-wise comparison processes until the consistency index was less than 0.1. After combining the priorities over all hierarchy, overall importance weights of experts were determined.

Taking aspect level as an example, we gather experts in a face-to-face meeting, and let them score disguisedly by themselves in the scale of 9/9–9/1 in a pairwise comparison. In a detail that, X_1 compares with X_2 to X_5, so there are ten groups totally. In the first round, every expert should compare the importance between X_1 and X_2 and score it. If there is a consistent scoring results relatively, the round is over, or until a agreement is achieved round after round. And then, a 55 original matrix will get (Table 30.2).

Then, we can get the total fuzzy weights of the complete advisory in Tables 30.3 and 30.4 and Fig. 30.3 shows the final weights of all the indexes.

Generally, most aspects considered by the technical advisory committee to develop high technology R&D programs. As shown in Table 30.3, the necessity of project has the highest weight, while basic conditions is the lowest, indicating that the necessity of project is the first considering factor when build up a R&D planning project. This finding is consistent with Kostoff [5].

Table 30.2 The original matrix from experts

	X_1	X_2	X_3	X_4	X_5
X_1	9/9	9/7	9/7	9/8	9/6
X_2	7/9	9/9	9/9	9/7	9/5
X_3	7/9	9/9	9/9	9/9	9/6
X_4	8/9	7/9	9/9	9/9	9/7
X_5	6/9	5/9	6/9	7/9	9/9

Table 30.3 The fuzzy weight of aspects

Symbol	Aspect	Weight
X_1	the necessity of project	0.25
X_2	the feasibility of program	0.22
X_3	the innovativeness	0.2
X_4	the results benefit	0.19
X_5	basic conditions	0.14

Table 30.4 The fuzzy weight of objectives

Objective	Weight	Rank
Topics direction	0.125	1
Topics significance	0.125	1
The contents of objective	0.0946	4
Implementation plan	0.0704	9
Appropriation budget	0.055	12
Theoretical innovation	0.056	10
Technological innovation	0.072	7
Application innovation	0.072	7
Expected results	0.0893	5
Anticipated benefit	0.1007	3
Research team	0.084	6
Research foundation	0.056	10

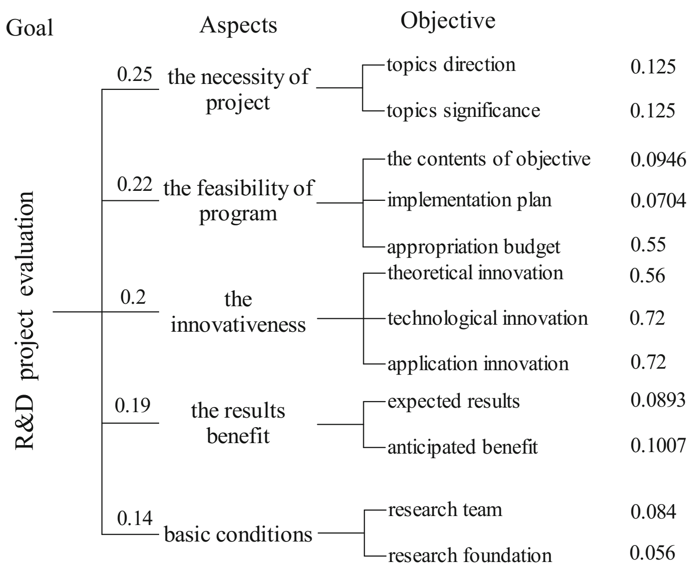


Fig. 30.3 The weights of the hierarchy model

In Fig. 30.3, the topics direction and topics significance (0.125) gets the highest weight, which indicates that the necessity of project is the most important factor, followed by anticipated benefit. This reflects the objectives and responsibilities of the R&D planning project.

30.4.3 Results

First, we determine the evaluation sets and give the scores as followings in Table 30.5. According to the fuzzy statistical method, we can get a fuzzy matrix of each factor from experts as followings,

Table 30.5 Evaluation of group

V	$V1$	$V2$	$V3$	$V4$
The degree of comment discriminant value	bad	common	good	very good
	0–25	25–50	50–75	75–100

$$\widetilde{B}_1 = \widetilde{W} \circ \widetilde{R}$$
$$= (0.125, 0.125, 0.0946, 0.0704, 0.055, 0.056, 0.072, 0.072, 0.072, 0.0893, 0.1007, 0.084, 0.056)$$
$$\circ \begin{bmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$
$$= (0.6033, 0.3407, 0.056, 0, 0)$$

Similarly, the evaluation results of other experts can be seen,

$$\widetilde{B}_2 = (0.125, 0.582, 0.293, 0, 0)\,,$$
$$\widetilde{B}_3 = (0.2746, 0.7254, 0, 0, 0)\,,$$
$$\widetilde{B}_4 = (0.6934, 0.3066, 0, 0, 0)\,,$$
$$\widetilde{B}_5 = (0.6233, 0.3767, 0, 0, 0)\,,$$
$$\widetilde{B}_6 = (0.3996, 0.6004, 0, 0, 0)\,,$$
$$\widetilde{B}_7 = (0.322, 0.4796, 0.1984, 0, 0)\,,$$
$$\widetilde{B}_8 = (0.1953, 0.8047, 0, 0, 0)\,,$$
$$\widetilde{B}_9 = (0.181, 0.819, 0, 0, 0)\,,$$
$$\widetilde{B}_{10} = (0.7019, 0.2981, 0, 0, 0)\,.$$

Then, to make the evaluation more objectivity and veracity, ten experts grade the R&D planning project depending on the familiarity on the project by Delphi (the weight of every expert is shown in Table 30.6), and use a Pyatyi-Likert scale from very good to bad.

Further more, we can get the final results as follows,

$$\widetilde{B} = \widetilde{W} \circ \widetilde{R} = (0.126, 0.083, 0.083, 0.164, 0.083, 0.083, 0.083, 0.126, 0.083, 0.083)$$
$$\circ \begin{bmatrix} 0.0754, 0.0429, 0.0070, 0, 0 \\ 0.0104, 0.0485, 0.0244, 0, 0 \\ 0.0229, 0.0605, 0, \quad 0, \quad 0 \\ 0, 0.1156, 0.0511, \quad 0, \quad 0 \\ 0.0519, 0.0314, 0, \quad 0, \quad 0 \\ 0.0333, 0.0500, 0, \quad 0, \quad 0 \\ 0.0268, 0.0399, 0.0165, 0, 0 \\ 0.0244, 0.1006, 0, \quad 0, \quad 0 \\ 0.0151, 0.0682, 0, \quad 0, \quad 0 \\ 0.0585, 0.0248, 0, \quad 0, \quad 0 \end{bmatrix}.$$
$$= (0.319, 0.582, 0.099, 0, 0)$$

Table 30.6 The weight of every expert

E_i	E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8	E_9	E_{10}
E_j	0.126	0.083	0.083	0.167	0.083	0.083	0.083	0.126	0.083	0.083

From the computation above, we can see that 31.9 % think this project is very good, and 58.2 % think is relatively good. This shows the project won the unanimous endorsement of experts. Moreover, taking the evaluation of group into view, we can get the final score is 84.39, belonging to V_4 group.

30.5 Conclusions and Future Research

We have proposed a new Delphi–AHP method to rank the criteria characterizing R&D planning project decision making in view of the existing defects in the project evaluation index system on the basis of the computation upon, we can get that this R&D planning project scores 84.39, which is a high grade relatively, showing that this project has a superior project value and a large potential to transform into achievement, should be given strong support.

To sum up, the new method to evaluate the R&D planning project has more maneuverability and practicability, which has proved that this indicator system can be used to evaluate the R&D planning project effectively. However, the management of R&D project not only includes the project assessment, but also process controlling, even more detailed is funds management. Therefore, we will deep study this problem such as general evaluation and so on in the future.

Acknowledgments This research was conducted with the support of soft science plan program of Sichuan in 2015 (No. 2015ZR0059) and soft science plan program of Chengdu in 2016 (No. 2015-RK00-00062-ZF).

References

1. Chandrasekaran A, Linderman K et al (2015) Managing R&D project shifts in high-tech organizations: a multi-method study. Prod Oper Manag 25:390–416
2. Chang B, Kuo C et al (2015) Using fuzzy analytic network process to assess the risks in enterprise resource planning system implementation. Appl Soft Comput 28:196–207
3. Doraszelski U, Jaumandreu J (2013) R&D and productivity: estimating endogenous productivity. Rev Econ Stud. doi:10.1093/restud/rdt011
4. Hsu YL, Lee CH, Kreng VB (2010) The application of fuzzy delphi method and fuzzy ahp in lubricant regenerative technology selection. Expert Syst Appl 37(1):419–425
5. Kostoff M (2000) Evaluation and information asymmetry: an examination of bid-ask spreads. J Account Res 35(3):181–194
6. Poh K, Ang B, Bai F (2001) A comparative analysis of r&d project evaluation methods. R&D Manag 31(1):63–75
7. Tonni I, Oliver R (2013) A delphi approach to define learning outcomes and assessment. Eur J Dent Edu 17(1):e173–e180
8. Zhu Wd, Liu F et al (2015) Research project evaluation and selection: an evidential reasoning rule-based method for aggregating peer review information with reliabilities. Scientometrics 105(3):1469–1490

Chapter 31
Adaptive Hybrid Genetic Algorithm with Modified Cuckoo Search for Reliability Optimization Problem

Youngsu Yun, Jungbok Jo and Mitsuo Gen

Abstract In this paper, an adaptive hybrid genetic algorithm with modified cuckoo search (MCS-AHGA) is proposed for effectively solving reliability optimization problems. For the proposed MCS-AHGA, a modified cuckoo search (MCS) which improves a weakness of conventional cuckoo search (CS) is adapted, and the genetic algorithm with an adaptive search scheme (AGA) is used. Hybridizing the MCS and the AGA can reinforce search quality and speed toward global optimal solution rather than hybridizing conventional CS and GA does. In numerical experiment, three types of reliability optimization problems are used for comparing the performance of the proposed MCS-AHGA with those of various conventional competing approaches including CS and GA. The experimental result proves that the proposed MCS-AHGA outperforms the competing conventional algorithms.

Keywords Adaptive hybrid genetic algorithm · Modified cuckoo search · Reliability optimization problem · Adaptive search scheme

31.1 Section Heading

For higher reliability of system, an important issue is to appropriately regulate a balance between reliability and other resources (e.g., cost, volume and weight). That is why due to system reliability measures such as adding redundant components or increasing component reliability leads to an increase in the resources required [1, 2].

Y. Yun (✉)
Division of Business Administration, Chosun University, Gwangju, Korea
e-mail: 1ysyun@chosun.ac.kr

J. Jo
Division of Computer Engineering, Dongseo University, Busan, Korea

M. Gen
Fuzzy Logic Systems Institute, Tokyo University of Science, Katsushika, Japan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_31

Generally speaking, three major ways to effectively guarantee higher system reliability exist. The first way is to increase the reliability of system components, the second one is to use redundant components using various sub-systems, and the last one is either to reassign system using interchangeable components or to combine the first and second ways [3–5]. The approaches for solving the three major ways can be categorized as follows [6]:

① Exact approaches based on dynamic programming, implicit enumeration [7], branch-and-bound [8]. ② Approximate approaches based on linear and nonlinear programming techniques [9]. Heuristic approaches based on tabu search, simulated annealing, neural network, and genetic algorithm (GA) etc.

Since 1970, numerous researchers have contributed to solve system reliability optimization problems using above mentioned approaches. Of them, especially, much more attentions and efforts have been devoted to improving an effectiveness of system reliability optimization problems using the heuristic approaches [10–16], since most of the exact and approximate approaches use a transformation of decision variables when solving system reliability optimization problems [6].

GA, one of the heuristic approaches, has been devoted to many system reliability optimization problems [1, 17, 18], since it has been demonstrated to converge to global optimal solutions for many diverse and difficult problems as a powerful and stochastic tool based on principles of natural evolution. Unfortunately, however, GA has a weakness in applying it to more complicated and precise design problems with various types of decision variables. Therefore, GA sometimes gets stuck at local optimal solutions instead of global optimal one. To overcome the weakness of GA, various hybridization approaches of GA with simulated annealing, neural network, hill climbing, etc. have been developed [19, 20]. Another weakness of GA is to take too much time for adjusting fine-tuning structure of GA parameters such as crossover and mutation rates. This kind of blindness may prevent GA from being really of practical interest for a lot of applications. To improve the weakness of this kind of blindness, various GAs with adaptive schemes have been developed [21–24]. By the adaptive schemes, GA parameters are automatically regulated during genetic search process. Therefore, much time for the fine-tuning of the parameters can be saved, and GA search ability can be improved in finding a global optimal solution.

For hybridization approaches, Lee et al. [11] proposed a hybrid approach using GA and hill climbing for reliability optimization problem with complex systems. Li and Jiang [25] proposed a new stochastic approach called the SA-GA-CA, which is based on the proper integration of a simulated annealing, a GA, and a chemotaxis algorithm for solving complex optimization problems. Gen and Cheng [17] introduced many types of hybrid approaches using GA, neural network, fuzzy logic, etc. in their book. For the GA with adaptive scheme.

For the GAs with adaptive schemes, Song et al. [22] used two fuzzy logic controllers (FLCs); one for the crossover rate and the other for the mutation rate. These parameters are considered as the input variables of GAs and are also taken as the output variables of the FLCs. Mak et al. [21] adaptively controlled the crossover and mutation rates according to the performance of GA operators. This heuristic scheme is based on the fact that it encourages well-performing operators to produce more efficient offspring, while reducing the chance for poorly performing operators to destroy the potential individuals, during genetic search process. Srinivas and Patnaik [23] also controlled the crossover and mutation rates according to the fitness values of the population at each generation. They recommended the use of adaptive crossover and mutation rates to maintain diversity in the population of each generation and to sustain the convergence property of the GA.

Based on the results of the conventional works mentioned above, we propose a new adaptive hybrid genetic algorithm with modified cuckoo search (MCS-AHGA) in this paper. For hybridization approach, a modified cuckoo search (MCS) which improved the performance of the CS developed by Yang and Deb [26] is used for constructing the MCS-AHGA. CS was proved to be an efficient approach for solving reliability optimization problems [4]. However, we find some weaknesses when hybridizing GA with CS in Kanagaraj et al. [3] and correct them in the MCS-AHGA. For the adaptive scheme, the method developed by Mak et al. [21] is incorporated into the MCS-AHGA. Since the proposed MCS-AHGA has both the hybrid ability and the adaptive ability, the performance can be compared with those of conventional hybrid approach by Kanagaraj et al. [3] and other hybrid approaches without adaptive scheme.

The rest of this paper is organized as follows. In Sect. 31.2, we describe reliability optimization problems and, as a main body, the procedure of the proposed MCS-AHGA is proposed in Sect. 31.3. The numerical experiments using three types of reliability optimization problems are presented and various performances using the proposed MCS-AHGA and competing approaches are analyzed in Sect. 31.4. Finally, Sect. 31.5 summarizes this study.

31.2 Reliability Optimization Problems

Typically, reliability optimization problems are classified into three types according to the usage of their decision variables: reliability allocation, redundancy allocation, and reliability redundancy allocation. Here, we formulate the reliability redundancy allocation type which consists of n stages into the general mathematical form of the non-linear separable integer programming problems as follows [1, 11]:

$$\max \; f(x) = \prod_{j=1}^{n} R_j(x_j) \tag{31.1}$$

$$\text{s.t.} \sum\nolimits_{j=1}^{n} g_{ij}(x_j) \; \leq \; b_j, \quad i = 1, 2, \ldots, m \tag{31.2}$$

$$x_j^L \leq x_j \leq x_j^U, \text{ integer}, \quad j = 1,\, 2,\, \ldots, n, \tag{31.3}$$

where $R_j\,(x_j)$ is the same as $1-(1-r_j)^{(x_j)}$ and the jth non-linear objective function representing a system reliability. r_j the known component reliability. $g_{ij}\,(x_j)$ the jth nonlinear function on the ith constraint which represents a system resource restraint. b_i the ith right-hand side or available source constraints. x_j^L and x_j^U are the lower and upper bounds for integer decision variables x_j, respectively. The objective is to determine the number of redundant components at each subsystem with the known component reliability while keeping the goal with a maximum reliability.

31.3 Design of MCS-AHGA

GA has been known as one of the powerful and broadly applicable stochastic optimization approaches [17]. In general, GA uses three types of operators (selection, crossover and mutation) during its search process. Selection is a process to produce respective solutions using survival of the fitness, Crossover is the swapping between two solutions. Mutation is the process of producing a new solution randomly.

The key characteristic of GA is to use the population which consists of many solutions. Therefore, GA has more chances to locate global optimal solution than the other approaches using single solution. Therefore, GA has been proved to be a versatile and effective approach for solving many optimization problems such as reliability optimization problems and engineering optimization problems [27]. Nevertheless, there are many situations where the conventional GA does not perform particularly well. First, GA sometimes suffers from premature convergence which it gets stuck at local optimal solutions instead of global optimal solution. Secondly, when the optimal solution region is located by GA, finding the global optimal solution within the region using GA becomes inefficient or impossible due to its random nature and global search. Thirdly, GA has no mechanism for automatically regulating GA parameters.

Therefore, to overcome the weaknesses of GA search mentioned above, various adaptive hybridization using GA and other conventional approaches have been studied by many researchers [17, 27, 28].

31.3.1 Hybridization Using GA and MCS

Similar to GA, CS is one of the latest nature-inspired metaheuristics algorithms, developed by Yang and Deb [26]. CS is based on the brood parasitism of some cuckoo species. In addition, this approach is enhanced by the so-called Lévy flights [26], rather than by simple isotropic random walks. For simplicity in describing CS approach, Yang and Deb [26] used the following three idealized rules:

- Each cuckoo lays one egg, which represents a set of solution co-ordinates, at a time and dumps it in a random nest.
- A fraction of the nests containing the best eggs, or solutions, will carry over to the next generation.

- The number of nests is fixed and there is a probability that a host can discover an alien egg. If this happens, the host can either discard the egg or the nest and this result in building a new nest in a new location.

Based on the above these 3 rules, the basic steps of CS can be summarized as follows: When generating new solution $s_i(t+1)$ for, say cuckoo i, a Lévy flight is performed as follows.

$$x_i(t+1) = x_i(t) + \alpha \oplus \text{Lévy}(\lambda), \tag{31.4}$$

where α is the step size which should be related to the scales of the problem of interest. In most cases, we can use $a = O(1)$. The product means entry-wise multiplications. The Lévy flights essentially provide a random walk, while their random steps are drawn from a Lévy distribution for large steps:

$$\text{Lévy}(\lambda) \cong t^{-\lambda} \quad (1 \leq \lambda \leq 3). \tag{31.5}$$

By these characteristic mentioned above, CS has been applied to many optimization problems and proved to be more efficient than other conventional approaches [29]. Recently, Kanagaraj et al. [3] proposed a hybrid approach using CS and GA. They combine the advantages of both CS and GA to locate global optimal solution in reliability optimization problems. Basic search schem is as follows: First, GA produces new population by its operators (selection, crossover and mutation). Secondly, using the new population of GA, CS produce a new solution by Lévy flight. Major characteristic of this hybrid approach is to locate the global optimal solution more quickly and precisely by using various and respective solutions during the hybrid search process. Therefore, they use Lévy flight to keep the production of various and respective solutions. However, the Lévy flight uses only one solution among all the solutions produced by GA operators (selection, crossover and mutation) and its use is done by only one time in every generation. Also, if the quality of the new solution produced by Lévy flight is not superior to that of the solution randomly selected in population produce by GA operators, the improvement of solution is impossible, which can make the production of the various and respective solutions difficult or impossible.

For constructing the proposed MCS-AHGA, we improve the weakness of the conventional hybrid approach by Kanagaraj et al. [3]. Main strategy is to always keep the production of the various and respective solutions during the hybrid approach process. To achieve the strategy, we modify conventional CS search scheme, that is, we apply Lévy flight to all the solutions produced by GA operators in every generation.

31.3.2 Adaptive Scheme

For adaptive scheme, the method developed by Mak et al. [21] is used. They used the fitness value of offspring in each generation in order to construct adaptive crossover and mutation operators: this scheme increases the occurrence rates of the crossover and mutation operators, if it consistently produces a better offspring during genetic search process; however, it also reduces the occurrence rates of the operators, if it produces a poorer offspring. This scheme based on the fact that it encourages the well-performing crossover and mutation operators to produce more offspring, while also reducing the chance for the poorly performing operators to destroy the potential individuals during genetic search process. It is the main scheme for constructing the AGO. The detailed procedure for maximization problem is as follows:

Procedure: regulation of p_C and p_M using the fitness of offspring

begin
  if $(\overline{f_{\text{off\_ size}}}(t)/\overline{f_{\text{pop\_size}}}(t)) - 1 \geq 0.1$
    then $p_C(t) = p_C(t-1) \times 0.05$, $p_M(t) = p_M(t-1) \times 0.005$;
  if $(\overline{f_{\text{off\_ size}}}(t)/\overline{f_{\text{pop\_ size}}}(t)) - 1 \leq -0.1$
    then $p_C(t) = p_C(t-1) \times (-0.05)$, $p_M(t) = p_M(t-1) \times (-0.005)$;
  if$-0.1 < (\overline{f_{\text{pop_size}}}(t)/\overline{f_{\text{off_size}}}(t)) - 1 < 0.1$
    then $p_C(t) = p_C(t-1)$, $p_M(t) = p_M(t-1)$
  end
end

where $\overline{f_{\text{off\_size}}}$ and $\overline{f_{\text{pop\_size}}}$ are the fitness values in offspring and parents, respectively. $p_C(t)$ and $p_C(t-1)$ are the crossover rates in a current generation and the previous generation, respectively. $p_M(t)$ and $p_M(t-1)$ are also the mutation rates in a current generation and the previous generation, respectively. In the cases of $(\overline{f_{\text{off\_size}}}(t)/\overline{f_{\text{pop\_size}}}(t)) - 1 \geq 0.1$ and $(\overline{f_{\text{off\_size}}}(t)/\overline{f_{\text{pop\_size}}}(t)) - 1 \leq -0.1$, the adjusted rates should not exceed the domain from 0.5 to 1.0 for the $p_C(t)$ and the domain from 0.00 to 0.10 for the $p_M(t)$.

The scheme of the procedure mentioned above is evaluated in every generation during genetic search process and changes the occurrence rates of crossover and mutation operators.

31.3.3 Detailed Implementation Procedure

Using the hybridization and the adaptive scheme mentioned in Subsects. 31.3.1 and 31.3.2 respectively, the implementation procedure of the MCS-AHGA is constructed as shown in Fig. 31.1.

```
procedure: MCS-AHGA
begin
  x_cur_best = 0                                   // x_cur_best : current best solution
  t ← 0;                                           // t: generation number
  initialize population P(t) from n host nest x_i (i = 1,2, …, n);
  evaluate P(t) and store the best solution x_best;
  while (t < max generation) or (termination criterion) do
    create C(t) from P(t) by selection, crossover and mutation routines;
    evaluate C(t)and store the best solution x_GA_best;
    for each solution x_i of C(t)do
       generate a new solution x_new from the x_i by taking Lévy flight;
       calculate fitness value F_new =f(x_new);
       choose a random solution x_i among C(t) and calculate the fitness value F_i = f(x_i);
       if (F_new > F_i) then
     x_i ← x_new , F_i ← F_new
       end
    end
    a fraction (p_a) of worst solutions are abandoned;
    regenerate new solutions randomly to replace the lost solutions;
    evaluate all solutions and store the best solution x_CS_best ;
    if (F(x_GA_best ) > F(x_CS_best )) then
         x_cur_best ← x_GA_best
    else
         x_cur_best ← x_CS_best
    end
    if (F(x_cur_best ) > F(x_best )) then
         x_best ← x_cur_best
    end
    apply adaptive scheme procedure described in sub-section 1.3.2 ;
    t ← t+1;
  end
  output: the best solution x_best;
end
```

Fig. 31.1 Implementation procedure of MCS-AHGA

31.4 Numerical Experiments

In this section, three types of reliability optimization problems are used for comparing the performance of the proposed MCS-AHGA with those of various conventional algorithms. Each type (T-1, T-2 and T-3) is the redundancy allocation problems of the serial-parallels with various subsystems. T-1 and T-2 were proposed by Tillman et al. [11] and Kuo et al. [8], respectively. T-3 was proposed by Rabi et al. [30]. For each type, the mathematical formulations are as follows:

T-1:

$$\max\ f(x) = \prod_{j=1}^{4} [1-(1-R_j)^{x_j}] \tag{31.6}$$

$$\text{s.t. } g_1(x) = \sum\nolimits_{j=1}^{4} (C_j \cdot x_j) \le 56 \tag{31.7}$$

$$g_2(x) = \sum\nolimits_{j=1}^{4} (W_j \cdot x_j) \le 120 \tag{31.8}$$

$$x_j \ge 0,\ \text{integer},\ j = 1, 2, 3, 4. \tag{31.9}$$

T-2:

$$\max\ f(x) = \prod_{j=1}^{15} [1-(1-R_j)^{x_j}] \tag{31.10}$$

$$\text{s.t. } g_1(x) = \sum\nolimits_{j=1}^{15} (C_j \cdot x_j) \le 400 \tag{31.11}$$

$$g_2(x) = \sum\nolimits_{j=1}^{15} (W_j \cdot x_j) \le 414 \tag{31.12}$$

$$1 \le x_j \le 10,\ \text{integer},\ j = 1, 2, \ldots, 15. \tag{31.13}$$

T-3:

$$\begin{aligned}\max\ f(x) = {} & [R_4(x_4)\cdot R_5(x_5)\cdot \Psi_1(x) + R_4(x_4)\cdot \overline{R}_5(x_5)\cdot \Psi_2(x) + R_5(x_5)\cdot \overline{R}_4(x_4)\cdot \Psi_3(x) \\ & + \overline{R}_4(x_4)\cdots \overline{R}_5(x_5)\cdots \Psi_3(x)]\cdots R_8(x_8)\cdots R_9(x_9)\cdots R_{10}(x_{10})\end{aligned} \tag{31.14}$$

$$\text{s.t. } g_1(x) = \sum\nolimits_{j=1}^{10}(C_j \cdot x_j) \le 125 \tag{31.15}$$

$$g_2(x) = \sum\nolimits_{j=1}^{10}(W_j \cdot x_j) \le 10000 \tag{31.16}$$

$$x_j^L \le x_j \le x_j^U\ : \tag{31.17}$$

where

$$\begin{aligned}\Psi_1(x) = {} & \prod_{j=1,2,3} R_j(x_j) + \prod_{j=1,7} R_j(x_j) + \prod_{j=3,6} R_j(x_j) + \prod_{j=6,7} R_j(x_j) - \prod_{j=1,2,3,7} R_j(x_j) \\ & - \prod_{j=1,2,3,6} R_j(x_j) - \prod_{j=1,6,7} R_j(x_j) - \prod_{j=3,6,7} R_j(x_j) + \prod_{j=1,2,3,6,7} R_j(x_j) \\ & - \prod_{j=1,2,3,6} R_j(x_j) - \prod_{j=1,6,7} R_j(x_j) - \prod_{j=3,6,7} R_j(x_j) + \prod_{j=1,2,3,6,7} R_j(x_j),\end{aligned} \tag{31.18}$$

$$\Psi_2(x) = \prod_{j=1,2,3} R_j(x_j) + \prod_{j=1,7} R_j(x_j) + \prod_{j=6,7} R_j(x_j) - \prod_{j=1,2,3,6} R_j(x_j) - \prod_{j=3,6,7} R_j(x_j), \tag{31.19}$$

$$\Psi_3(x) = \prod_{j=1,2,3} R_j(x_j) + \prod_{j=3,6} R_j(x_j) + \prod_{j=6,7} R_j(x_j) - \prod_{j=1,2,3,6} R_j(x_j) - \prod_{j=3,6,7} R_j(x_j), \tag{31.20}$$

$$\Psi_4(x) = \prod_{j=1,2,3} R_j(x_j) + \prod_{j=6,7} R_j(x_j) - \prod_{j=1,2,3,6,7} R_j(x_j), \tag{31.21}$$

$$R_j(x_j) = 1 - \bar{R}_j(x_j) \quad j = 1, 2, \ldots, 10, \tag{31.22}$$

$$\bar{R}_j(x_j) = (1 - R_j)^{x_j} \quad j = 1, 2, \ldots, 10. \tag{31.23}$$

For the T-1, T-2 and T-3, the global optimal solutions were already known as = 0.9975 with = {5, 6, 5, 4}, = 0.9456 with = {3, 4, 5, 3, 3, 2, 4, 5, 4, 3, 3, 4, 5, 5, 5}, and = 0.9966 with = {1, 2, 1, 1, 1, 5, 5, 5, 6, 6}, respectively.

For various comparisons, some conventional approaches are used and their performances are com-pared with that of the proposed MCS-AHGA. They are summarized as shown in Table 31.1.

All the approaches shown in Table 31.1 were programmed in Visual Basic Version 6.0 and ran on the environment of IBM compatible PC Pentium processor (Intel core i7-2600), CPU 3.4 GHz, 4 GB RAM and Window 7. The parameter settings for the five conventional approaches and the proposes MCS-AHGA listed in Table 31.1 are as follows: population size is 20, crossover rate 0.5, and mutation rate 0.1 for the GA, LS-GA, CS-GA, MCA-HGA and MCS-AHGA. However, the crossover and mutation rates for the proposed MCS-AHGA are automatically regulated during the genetic search process. Number of host nests, is 20, 1, and 0.25 for the CS, CS-GA, MCS-HGA and MCS-AHGA, the range of local search is 1.00 for LS-GA. Total number of generations is 2,000 for all approaches. All together 20 independent runs were made to eliminate the randomness of each approach. All the approaches are compared with each other using various measures of performance shown in Table 31.2.

Table 31.1 Approaches for comparison

Approach	Description	Type
CS	Cuckoo search by Yang and Deb [26]	Single
GA	Genetic algorithm by Gen and Chang [17]	”
LS-GA	GA with IHC by Yun et al. [28]	Hybridization
CS-GA	GA with CS by Kanagaraj et al. [3]	”
MCS-HGA	GA with Modified CS by Yun et al. [31]	”
MCS-AHGA	Proposed approach in this paper	”

Table 31.2 Measures of performance

Measure	Description
Best solution	Best solution
ANG	Average number of generation
ANS	Average number of getting stuck at local optimal solutions
CPU time	Average CPU time (unit: sec.)

The ANG indicates the average number of generations during each approach reaches to global optimal solution in 20 trials. If an approach does not locate its global optimal solution in a trial, the ANG is calculated by a pre-defined maximum number of generations. The CPU time is the averaged running time over 20 independent trials at each approach. Using various measures of performance described in Table 31.2, each approach including the proposed MCS-AHGA have been run and their performance results are summarized in Table 31.3.

For the T-1 of Table 31.3, all approaches located the global optimal solution in terms of best solution. However, in terms of the ANG, the performances of the MCS-HGA and the proposed MCS-AHGA are significantly better than those of the GA, CS, LS-GA, and CS-GA. Also the CS outperforms the CS-GA in terms of the ANG, even though the latter has the hybrid ability using CS and GA, This result is affected by the ANS, that is, the CS-GA locates the global optimal solution in only three trials, but the CS locates the global optimal solution in all trials. In terms of the CPU, both the MCS-HGA and the proposed MCS-AHGA showed the quickest search time, while the CS-GA the slowest search time, when approaching to the global optimal solution known.

For the T-2, in terms of the best solution, ANG and ANS, the global optimal solution is located in the LS-GA, MCS-HGA and MCS-AHGA. However, in comparison among them, the MCS-AHGA is more efficient than the others, since the performance of the MCS-AHGA is significantly superior to those of the others in terms of the ANG and ANS. For the T-3, in terms of the best solution, the GA, LS-GA, MCS-HGA and MCS-AHGA locate the global optimal solution, but the CS and CS-GA do not locate it even on one occasion. In the comparison among the GA, LS-GA, MCS-HGA and MCS-AHGA, the LS-GA, MCS-HGA and MCS-AHGA locate the global optimal solution in all the trials, while GA locates it in just one trial

Table 31.3 Computation result for T-1, T-2, and T-3

		GA	CS	LS-GA	CS-GA	MCS-HGA	MCS-AHGA
T-1	Best sol.	0.9975	0.9975	0.9975	0.9975	0.9975	0.9975
	ANG	636	454	550	1,775	220	215
	ANS	1	0	2	17	0	0
	CPU time	0.02	0.04	0.04	0.23	0.01	0.01
T-2	Best sol.	0.909	0.857	0.9456	0.9069	0.9456	0.9456
	ANG	2,000	2,000	1,926	2,000	951	450
	ANS	20	20	19	20	15	3
	CPU time	0.69	2.18	0.86	2.34	0.9	0.75
T-3	Best sol.	0.9966	0.9942	0.9966	0.9911	0.9966	0.9966
	ANG	1,925	2,000	96	2,000	69	35
	ANS	19	20	0	20	0	0
	CPU time	0.23	0.38	0.23	0.48	0.04	0.02

in terms of ANS. Similar to the comparison in T-1, MCS-AHGA showed the best results by the ANG and CPU time.

Base on the above analysis results, we can reach the following conclusions:

- The hybrid approaches (LS-GA and CS-GA), except for the MCS-HGA and MCS-AHGA, do not show any benefits rather than the single approach (GA, CS), which means that a balance between exploitation and exploration does not be well regulated during their searching toward global optimal solution known, while the MCS-HGA and MCS-AHGA well regulates the balance rather than the other competing hybrid approaches (LC-GA and CS-GA). This analysis implies that a proper balance between exploitation and exploration is very important when hybrid approaches tries to locate global optimal solution.
- In the comparison between MCS-HGA and MCS-AHGA, the latter has showed to be significantly better performance than the former, which is caused by the property that the latter has an adaptive scheme to automatically regulate crossover and mutation rates during genetic search process, but the former has not.
- When the complexity of the problem under consideration is increasing, the chance to locate global optimal solution can be also reduced, though the proposed MCS-AHGA has proved to be more efficient than the other competing approaches. Therefore, a necessity of suitable hybridization and adaptive scheme strategy using the properties of each approach should be required to guarantee search quality and speed.

31.5 Conclusions

Many approaches to effectively solve reliability optimization problems have been suggested in conventional literatures. In this paper, we proposed anadaptive hybrid approach using modified CS and GA with adaptive scheme, called MCS-AHGA. The proposed MCS-AHGA is an improved approach of the conventional hybrid approach by Kanagaraj et al. [3]. For the proposed MCS-AHGA, we used the modified CS (MCS) which overcomes a weakness of conventional CS used in the hybrid approach. In conventional CS, Lévy flight uses only one solution among all the solutions resulting from GA operators (selection, crossover and mutation) and its use is done by only one time in every generation. Also, if the solution produced by the use of Lévy flight does not outperforms that randomly selected in population resulting from GA operators, the improvement of solution is impossible. Therefore, the conventional CS sometimes fails to produce various and respective solutions. To overcome this weakness of the conventional CS application in hybrid approach, in the proposed MCS-AHGA, we used an improved strategy which Lévy flight is adapted to all the solutions produced by GA operators in every generation. Also, an adaptive scheme for automatically regulating GA operators (crossover and mutation rates) is used in the proposed MCS-AHGA.

The detailed implementation procedure of the proposed MCS-AHGA was suggested as a pseudo code. In numerical experiments, there types of reliability optimization problems were presented to compare the performance of the proposed MCS-AHGA with those of conventional other competing approaches including the hybrid approach by Kanagaraj et al. [3]. The computation results under the same computational environment showed that the proposed MCS-AHGA is more efficient in various measures of performance than the other competing approaches. However, in this paper, we only used three reliability optimization problems. Therefore, the reliability optimization problems with more complex and various types of decision variables should be used and tested for proving the efficiency of the proposed MCS-AHGA.

Acknowledgments This work is partly supported by JSPS: Grant-in-Aid for Scientific Research (C; No. 15K00357) and by the National Research Foundation of Korea Grant funded by the Korean Government (NRF- 2014S1A5A2A01010951). This paper is a revised and extended version of the paper which was presented in 45th International Conference on Computers and Industrial Engineering, Metz, France, 2015.

References

1. Gen M, Yun Y (2006) Soft computing approach for reliability optimization: state-of-the-art survey. Reliab Eng Syst Saf 91(9):1008–1026
2. Kuo W, Wan R (2007) Recent advances in optimal reliability allocation. In: Computational intelligence in reliability engineering. Springer, pp 1–36
3. Kanagaraj G, Ponnambalam S, Jawahar N (2013) A hybrid cuckoo search and genetic algorithm for reliability-redundancy allocation problems. Comput Ind Eng 66(4):1115–1124
4. Valian E (2014) Solving reliability optimization problems by cuckoo search. In: Cuckoo search and firefly algorithm. Springer, pp 195–215
5. Valian E, Tavakoli S, Mohanna S, Haghi A (2013) Improved cuckoo search for reliability optimization problems. Comput Ind Eng 64(1):459–468
6. Prasad V, Kuo W (2000) Reliability optimization of coherent systems. IEEE Trans Reliab 49(3):323–330
7. Geoffrion AM (1969) An improved implicit enumeration approach for integer programming. Oper Res 17(3):437–454
8. Kuo W (2001) Optimal reliability design: fundamentals and applications. Cambridge University Press, Cambridge
9. Ha C, Kuo W (2005) Multi-path approach for reliability-redundancy allocation using a scaling method. J Heuristics 11(3):201–217
10. Agarwal M, Sharma VK (2010) Ant colony approach to constrained redundancy optimization in binary systems. Appl Math Model 34(4):992–1003
11. ChangYoon L, YoungSu Y (2002) Reliability optimization design for complex systems by hybrid ga with fuzzy logic control and local search. IEICE Trans Fundam Electron Commun Comput Sci 85(4):880–891
12. Kulturel-Konak S, Smith AE, Coit DW (2003) Efficiently solving the redundancy allocation problem using tabu search. IIE Trans 35(6):515–526
13. Vo Bay, Hong TP, Le B (2009) An efficient particle swarm approach for mixed-integer programming in reliability-redundancy optimization applications. Reliab Eng Syst Saf 94(4):830–837

14. Tavakkoli-Moghaddam R, Safari J, Sassani F (2008) Reliability optimization of series-parallel systems with a choice of redundancy strategies using a genetic algorithm. Reliab Eng Syst Saf 93(4):550–556
15. Wu P, Gao L et al (2011) An improved particle swarm optimization algorithm for reliability problems. ISA Trans 50(1):71–81
16. Zou D, Gao L et al (2011) An effective global harmony search algorithm for reliability problems. Expert Syst Appl 38(4):4642–4648
17. Gen M, Cheng R (2000) Genetic algorithms and engineering optimization, vol 7. Wiley, New York
18. Gen M, Kim JR (1999) GA-based reliability design: state-of-the-art survey. Comput Ind Eng 37(1):151–155
19. ChangYoon L, Way K (2001) Reliability optimization design using a hybridized genetic algorithm with a neural-network technique. IEICE Trans Fundam Electron Commun Comput Sci 84(2):627–637
20. Mukuda M, Yun Y, Gen M (2004) Adaptive genetic local search algorithms for solving reliability optimization problems. IEEJ Trans Electron Inf Syst 124(10):1986–1990
21. Mak K, Wong Y, Wang X (2000) An adaptive genetic algorithm for manufacturing cell formation. Int J Adv Manuf Technol 16(7):491–497
22. Song Y, Wang G, Wang P, Johns A (1997) Environmental/economic dispatch using fuzzy logic controlled genetic algorithms. In: Generation, transmission and distribution, IEE proceedings, IET, vol 144, pp 377–382
23. Srinivas M, Patnaik LM (1994) Adaptive probabilities of crossover and mutation in genetic algorithms. IEEE Trans Syst Man Cybern 24(4):656–667
24. Yun Y, Gen M (2003) Performance analysis of adaptive genetic algorithms with fuzzy logic and heuristics. Fuzzy Optim Decis Mak 2(2):161–175
25. Li B, Jiang W (2000) A novel stochastic optimization algorithm. IEEE Trans Syst Man Cybern Part B Cybern 30(1):193–198
26. Yang XS, Deb S, (2009) Cuckoo search via lévy flights. In: World congress on nature & biologically inspired computing, (2009) NaBIC 2009. IEEE, pp 210–214
27. Yun YS (2005) Study on adaptive hybrid genetic algorithm and its applications to engineering design problems
28. Yun Y, Gen M, Seo S (2003) Various hybrid methods based on genetic algorithm with fuzzy logic controller. J Intell Manuf 14(3–4):401–419
29. Yang XS (2013) Cuckoo search and firefly algorithm: theory and applications, vol 516. Springer, Switzerland
30. Ravi V, Murty B, Reddy P (1997) Nonequilibrium simulated-annealing algorithm applied to reliability optimization of complex systems. IEEE Trans Reliab 46(2):233–239
31. Yun YS, Jo JB, Gen M (2015) Hybridization of modified cuckoo search and genetic algorithm for reliability optimization problems. In: 45th international conference on computers and industrial engineering, (CIE45), pp 1–13

Chapter 32
Generating Distributions Through Convolution of Characteristic Functions

Syed Ejaz Ahmed, Mohamed Amezziane and Wesley Wieczorek

Abstract Financial data such as asset returns, exchange rates, or option prices cannot be modeled effectively by classical distributions such as the Gaussian. These types of data have probability density functions that are thick-tailed and negatively skewed. To account for these features, we propose a new method of generating classes of distribution functions through convolution of smooth and non-smooth characteristic functions where the smoothing parameter is used to control the thickness of the density tails. To illustrate the advantages of using such class of distributions, we consider special cases in which the smooth characteristic functions are of those of the uniform, the normal and the compact supported cosine distributions and the non-smooth is the characteristic function of the Cauchy distribution. As a comparison criterion between distributions, we use the Stiltjes-Hamburger conditions for moments' existence and show how the proposed distributions outperform the Student and Pearson IV distributions, which are commonly used by financial engineers to model stock returns.

Keywords Distribution theory · Financial modeling · Kurtosis · Skewness · Moments existence problem

---

S. Ejaz Ahmed (✉)
Department of Mathematics and Statistics, Brock University, Brock,
St. Catharines, ON L2S 3A1, Canada
e-mail: sahmed5@brocku.ca

M. Amezziane
Central Michigan University, Mount Pleasant, MI 48859, USA

W. Wieczorek
Zurich International, Zurich, Switzerland

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_32

32.1 Introduction

Statistical investigations of the price movement of financial data over the last sixty years has led financial analysts to observe that disparate and unrelated assets from different markets, such as stock shares, commodities, and exchange rates, share common statistical properties, which are known in the financial sector as stylized facts. Cont [1] has summarized the results of such studies in a list of 11 stylized facts about the distribution of asset returns, 3 of which are distribution-related: (1) The returns' distributions have heavy tails (2) The returns' distributions are asymmetric (3) The returns' distributions become close to a Gaussian at low frequencies. For a thorough investigation of these stylized facts we refer the reader to current financial econometrics literature [2, 3].

To illustrate these stylized facts, we consider the daily log-returns from May 2001 to May 2011 of two stock market indices: the Dow Jones Industrial Average (DJIA) and the Standard & Poor's 500 (SP500). DJIA comprises 30 common stocks of large American companies while SP500 consists of 505 common stocks traded on American stock exchanges. Both data sets consist of 2515 log-returns (Fig. 32.1).

The above two time series plots and histograms show that the two indices display similar behaviours even though they represent different companies. The histogram plots show major discrepancies between the normal density estimate (red curve) and the underlying density of the log returns. This lack-of-fit of the normal distribution is confirmed by the Jarque–Bera and the Kolmogorov–Smirnov tests of normality, as well as by the Anscombe test of kurtosis, all shown in the table below, thus supporting the first listed stylized fact. Finally, the outcome of the D'agostino skewness tests for both data sets support the second stylized fact (Fig. 32.2).

To illustrate the third stylized fact, we analyze the annual log-returns of the DJIA and SP500 indices between 1985 and 2005, a trading era with one mild market crash. As evinced in the graph below, the normality plots, the small values of skewness and

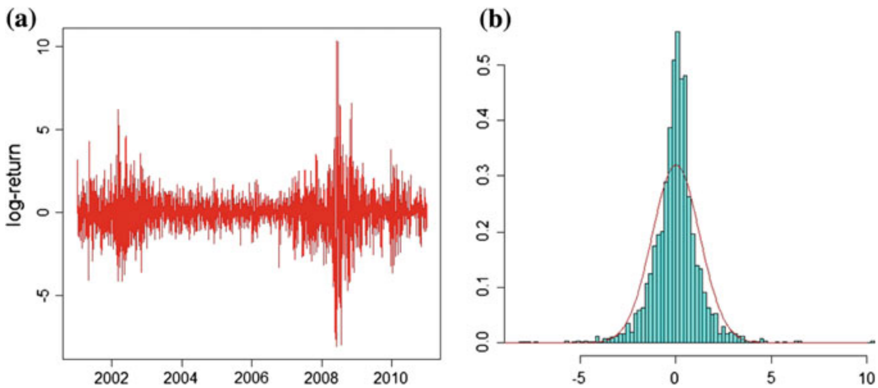


Fig. 32.1 Time series and histogram plots of DJIA log-returns

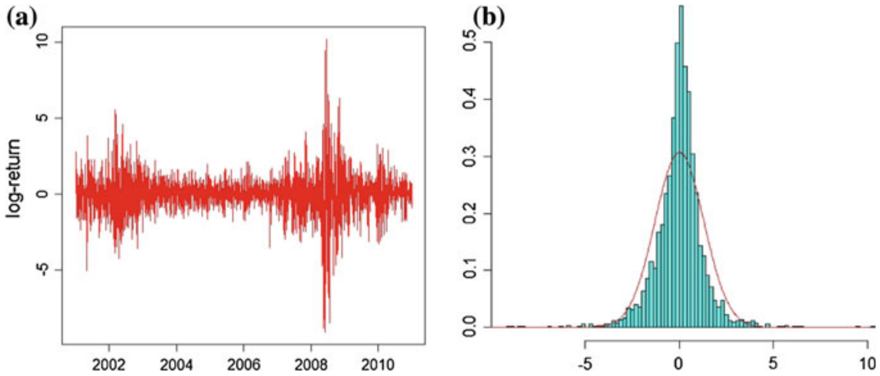


Fig. 32.2 Time series and histogram plots of SP500 log-returns

Table 32.1 Descriptive statistics, and lack-of-fit tests for DJIA and SP500 log-returns

Statistic	DJIA	SP500
min	−8.103	−9.127
max	10.376	10.246
mean	0.018	0.009
median	0.059	0.070
s.d.	1.248	1.300
skewness	0.110	−0.189
kurtosis	11.579	11.356
J-B p-value	<0.001	<0.001
K-S p-value	<0.001	<0.001
D'agostino p-value	<0.001	<0.001
Anscombe p-value	<0.001	<0.001

excess kurtosis, and the results of Kolmogorov–Smirnov test for the two series all support the validity of the third listed stylized fact that the distribution of returns (or log-returns) approaches that of a normal over long trading periods and hence distributions, with infinite four first moments such as some Levy alpha-stable distributions, might not be good fits (Fig. 32.3) (Table 32.1).

Based on these stylized facts, a distribution that is fit for modeling financial assets should be flexible enough to allow for different values of the skewness and kurtosis coefficients. Finding such distributions is related to the problem of moments' existence conditions originally studied by Stiltjes [4] in the case of compactly supported distributions and Hausdorff [5, 6] who obtained necessary and sufficient conditions for the existence of a moment sequence. Hamburger [7] studied the same problem in the case of unbounded distributions, while Widder [8] formulated the moments' existence conditions as the following sequence of inequalities of moments' determinants, that is, $\{\mu'_k\}_{k=1}^{\infty}$ is definite if:

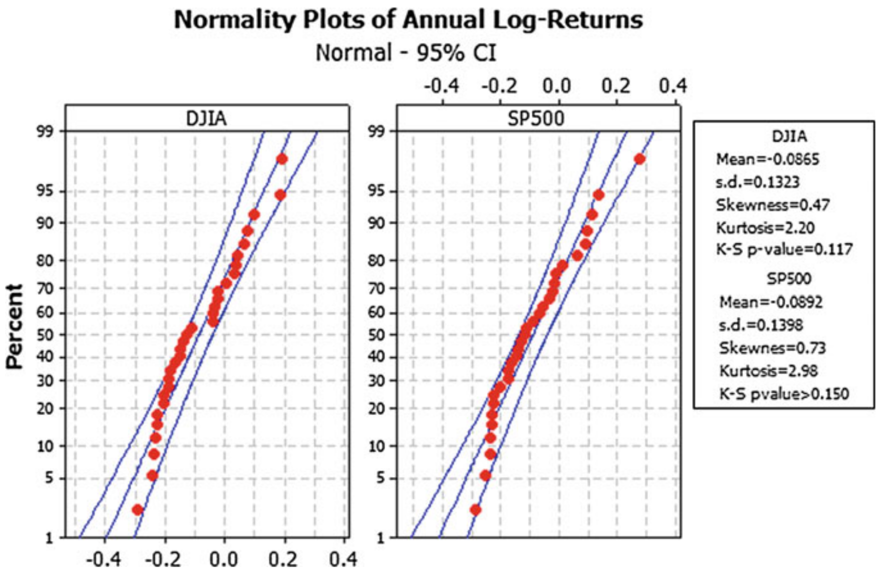


Fig. 32.3 Normality plots of annual log-returns

$$\mu_0' \geq 0, \quad \begin{vmatrix} \mu_0' & \mu_1' \\ \mu_1' & \mu_2' \end{vmatrix} \geq 0, \quad \begin{vmatrix} \mu_0' & \mu_1' & \mu_2' \\ \mu_1' & \mu_2' & \mu_3' \\ \mu_2' & \mu_3' & \mu_4' \end{vmatrix} \geq 0, \quad \ldots, \tag{32.1}$$

where $\mu_j' = \int x^j dF(x)$; $j = 0, 1, \ldots$.

Without loss of generality, if we choose $\mu_1' = \mu = 0$ and $\mu_2' = \sigma^2 = 1$ and note that $\mu_0 = 1$, then the skewness and kurtosis coefficients become $\mu_3' = s$ and $\mu_4' = \kappa$ and the third inequality in (32.1) becomes:

$$\begin{vmatrix} 1 & 0 & 1 \\ 0 & 1 & s \\ 1 & s & \kappa \end{vmatrix} = \kappa - s^2 - 1 \geq 0, \tag{32.2}$$

which implies that $s^2 \leq \kappa - 1$.

The inequality describes the area within a parabola that represents the boundary of the maximum area that a given distribution with finite third and fourth moments may occupy. So, a distribution whose skewness and kurtosis coefficients are not inside the parabola resulting from inequality (32.2) does not exist. This is illustrated in Fig. 32.4.

Several methods have been devised to address the issue of obtaining classes of distributions that cover as much as possible of the area inside the parabola in the above figure. In particular, Gram-Charlier and Edgeworth expansions about the normal distribution were used to produce asymmetric distributions with moderately large kurtosis [9–11]. However, the domain of permissible skewness and kurtosis is

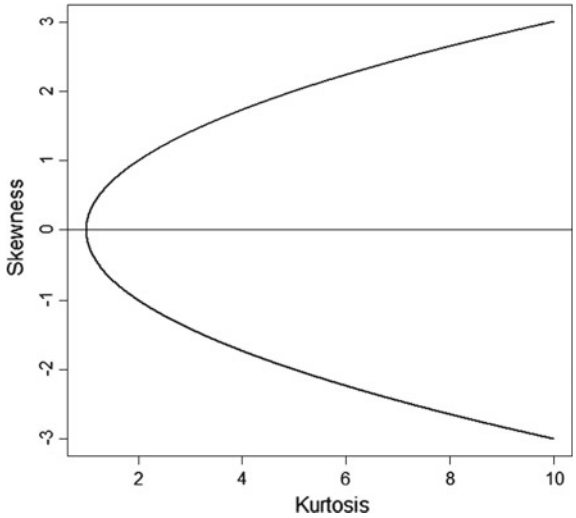


Fig. 32.4 Skewness Kurtosis domain of existence

compact and does not allow values of kurtosis larger than 7 [12]. The Pearson type IV distribution fares much better since it covers an unbounded subset of the domain of existence [3]. A comparable performance is achieved by the skewed Student distribution [13–15]. For more on distributions that capture the statistical properties of financial assets, we refer the reader to Jondeau et al.'s text [3]. It is noteworthy that of all commonly used distributions, Pearson type IV and Student distributions are the most flexible when it comes to capturing the asymmetry and thick-tailedness of the returns.

The objective of this paper is to derive a method for generating classes of flexible distributions that attain a wide range of skewness and kurtosis values. We present this methodology in Sect. 32.2, then we list examples of proposed distributions generated through the new method in Sect. 32.3. We compare the performances of the new distributions to the popular ones in Sect. 32.4. Concluding remarks and future work will be described in Sect. 32.5.

32.2 Generating Asymmetric and Thick-Tailed Distributions

32.2.1 Inducing Thick-Tailedness by Convolution of Characteristic Functions

Consider two density functions: a thin-tailed f_1 and a thick-tailed f_2, and denote their characteristic functions by φ_1 and φ_2. The nature of the tails of densities f_1 and f_2

dictate that φ_1 is a "smooth" function while φ_2 is a "rough" function. Here, function smoothness entails that the function is at least once differentiable. Now consider the characteristic function φ defined as:

$$\varphi(t) = \frac{\varphi_{1,\eta} * \varphi_2(t)}{\varphi_{1,\eta} * \varphi_2(0)} = \frac{\int \varphi_{1,\eta}(t-s)\,\varphi_2(s)\,ds}{\int \varphi_{1,\eta}(-s)\,\varphi_2(s)\,ds},$$

where $\varphi_{1,\eta}(t) = \eta\varphi_1(\eta t)$.

The convolution of φ_1 and φ_2 can be either smooth or rough, depending on the smoothing parameter η. Hence, depending on the same parameter η, the density function $f(x) = \frac{f_1(\eta x) f_2(x)}{\varphi_{1,\eta} * \varphi_2(0)}$ whose characteristic function is φ, can vary between thin and thick-tailed. This follows from the facts that the characteristic function is the Fourier transform of the density function, and that the inverse Fourier transform of a convolution of $\varphi_{1,\eta}$ and φ_2 is the product of f_1 and f_2. Therefore, the parameter η can be used, in general, to control the weight of the tails and in particular to control the distribution kurtosis.

The method described above can be used with any two or more densities to generate new families of distributions, regardless of the nature of the tails of the original densities. The underlying technique has been extensively used in signal and image processing and nonparametric function estimation to isolate random noise from signal functions. For more details on this technique, the reader is referred to [16].

32.2.2 *Inducing Skewness in a Symmetric Distribution*

To induce skewness in the distributions generated by the method described earlier, we consider two popular and easy-to-use methods:

(1) The inverse scale factor method [13, 17]: $f(x)$ is a symmetric density, then an asymmetric density, $g(x)$ can be generated as:

$$g(x;\xi) = \frac{2}{(\xi + \xi^{-1})} f\left(x\xi^{-\mathrm{sign}(x)}\right),$$

where $\xi > 0$ is the skewness parameter. The parameter ξ controls the shape of the curve and determines how much of the distribution is allocated towards the left ($\xi < 1$) or the right ($\xi > 1$) of the origin. Note that when $\xi = 1$, g reverts back to f.

(2) The hidden truncation method [17]: $f(x)$ is a symmetric density function with CDF $F(X)$, then an asymmetric distribution $g(x)$ can be generated as:

$$g(x) = 2f(x)F(x\xi),$$

where ξ is the skewness parameter. The density $g(x)$ is skewed to the right (left) when $\xi > 0$ ($\xi < 0$). Note that when $\xi = 0$, g reverts back to f.

32.3 Examples Tempered Cauchy Distributions

We consider three examples of distributions obtained by "toning down" the tails of the Cauchy distribution. The "rough" characteristic function in this case will be that of the Cauchy distribution: $\varphi_2(t) = exp\,(-\,|t|)$, while the "smooth" characteristic functions will be those of the uniform, normal and compact-supported cosine distributions.

32.3.1 Asymmetric Truncated Cauchy Distribution

By multiplying the Cauchy density by the uniform, the normalized product corresponds to a truncated Cauchy density. The resulting distribution is:

$$f(x;\eta) = \frac{1}{2\arctan(\eta)} \times \frac{1}{1+x^2}\mathbf{1}(|x| < \eta).$$

Below are plots of the density for different values of η. Using the inverse scale factor method, we define the Asymmetric Truncated Cauchy distribution (ATC) as:

$$g(x) = \frac{1}{2\arctan(\eta)\left(\xi+\xi^{-1}\right)}\frac{1}{1+\left(x\xi^{-sign(x)}\right)^2}\mathbf{1}(|x| < \eta\xi^{sign(x)}).$$

Below are plots of the ATC distribution for $\eta = 5$ and varying values of ξ (Fig. 32.5).

The first four half raw moments of the Truncated Cauchy need to be computed in order to find the first four raw moments of the ATC, which are used to find the mean,

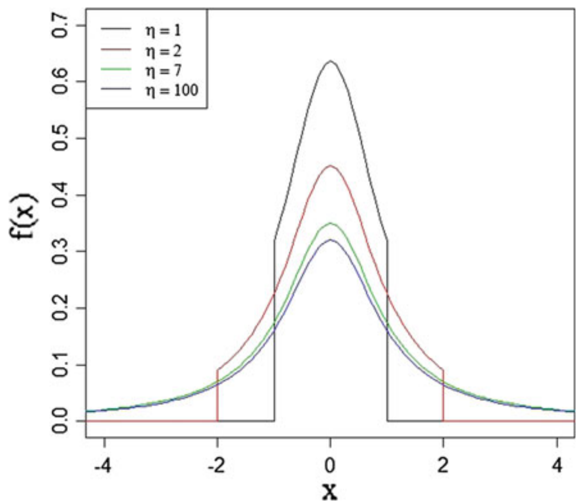


Fig. 32.5 Truncated Cauchy PDF

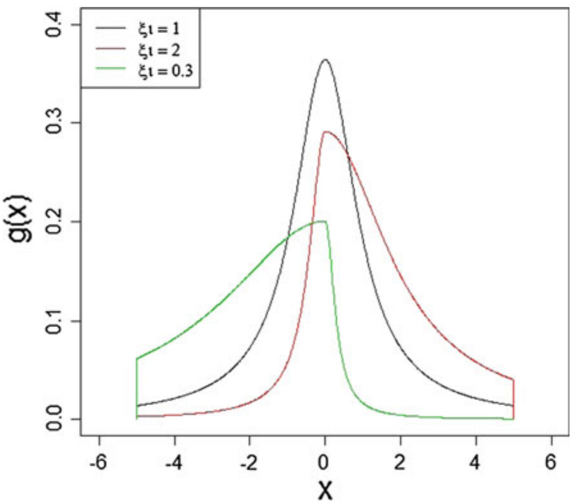


Fig. 32.6 Asymmetric Truncated Cauchy PDF for $\eta = 5$

variance, skewness, and kurtosis of the distribution. These moments can be found by computing the following integral:

$$\tilde{m_k} = \frac{1}{2}E(X^k) = \frac{1}{2\arctan(\eta)}\int_0^{\eta}\frac{x^k}{1+x^2}dx.$$

The half moments are used to evaluate the moments of the ATC:

$$\mu_1 = \frac{(\xi^2 - \xi^{-2})}{\xi + \xi^{-1}} \times \frac{\ln\left(1+\eta^2\right)}{2\arctan(\eta)},$$
$$\mu_2' = \frac{(\xi^3 + \xi^{-3})}{\xi + \xi^{-1}} \times \left[\frac{\eta}{\arctan(\eta)} - 1\right],$$
$$\mu_3' = \frac{(\xi^4 - \xi^{-4})}{\xi + \xi^{-1}} \times \frac{\eta^2 - \ln\left(1+\eta^2\right)}{2\arctan(\eta)},$$
$$\mu_4' = \frac{(\xi^5 + \xi^{-5})}{\xi + \xi^{-1}}\left(1 + \frac{\eta(\eta^2 - 3^2)}{3\arctan(\eta)}\right).$$

The above formula can be used to compute variance, skewness, and kurtosis. These results are omitted since their equations are cumbersome, especially those of skewness and kurtosis (Fig. 32.6).

A slightly different version of the ATC distribution can be generated using the hidden truncation method due to the existence of a closed form of the Truncated Cauchy's CDF. The CDF $F(x)$ can be defined as

$$F(x) = \left(\frac{1}{2} + \frac{1}{2}\frac{\arctan(x)}{\arctan(\eta)}\right)\mathbf{1}(|x| < \eta) + \mathbf{1}(x > \eta) \qquad (32.3)$$

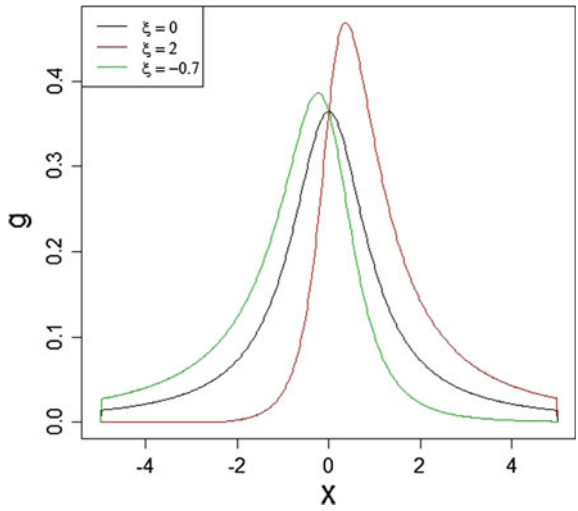


Fig. 32.7 ATC for various ξ with $\eta = 5$

The density function $g(x)$ is then

$$g(x) = \frac{1}{\arctan(\eta)(1+x^2)}\left(\frac{1}{2} + \frac{1}{2}\frac{\arctan(x\xi)}{\arctan(\eta)}\right)\mathbf{1}\left(|x| < \eta \min\left(1, \xi^{-1}\right)\right).$$

Below is a plot of $g(x)$ for various levels of ξ where η was held constant at 5 (Fig. 32.7).

Due to the dependence of the support of g on ξ and η, we are obligated to consider different situations. For the simpler case, when $|\xi| < 1$, the k^{th} raw moment can be found by

$$E(X^k; |\xi| < 1) = \frac{1}{2(\arctan \eta)}\left(\frac{1}{\arctan \eta}\int_{-\eta}^{\eta} \frac{x^k \arctan(x\xi)}{1+x^2}\,dx + \int_{-\eta}^{\eta} \frac{x^k}{1+x^2}\,dx\right).$$

The closed form of the latter integral is well known. However, for the former, when k is an even positive integer, it integrates to 0, but when k is odd, we use the following integral function, $AC(a)$:

$$AC(a) = \int_{-a}^{a} \frac{x \arctan(x\xi)}{1+x^2}\,dx.$$

We obtain the raw moments for $k = 1, 2, 3, 4$ when $|\xi| < 1$. These can be used to formulate variance, skewness, and kurtosis.

$$\mu = \frac{AC(\eta)}{2(\arctan(\eta))^2},$$
$$\mu_2' = \frac{\eta}{\arctan(\eta)} - 1,$$
$$\mu_3' = \frac{1}{2(\arctan(\eta))^2}\left[\frac{((\eta\xi)^2+1)\arctan(\eta\xi) - \eta\xi}{\xi^2} - \ln(1+\eta^2)\arctan(\eta) - AC(\eta) + \eta^2\right],$$
$$\mu_4' = \frac{\eta(\eta^2-3)}{3\arctan(\eta)} + 1.$$

Note that the raw moment is independent of ξ for k even.

When $|\xi| \geq 1$, the *kth* raw moment of $g(x)$ can be defined as

$$E(X^k; |\xi| \geq 1) = \frac{1}{2(\arctan(\eta))}\left(\frac{1}{\arctan(\eta)}\int_{\frac{-\eta}{|\xi|}}^{\frac{\eta}{|\xi|}} \frac{x^k \arctan(x\xi)}{1+x^2}\,dx + \int_{\frac{-\eta}{|\xi|}}^{\frac{\eta}{|\xi|}} \frac{x^k}{1+x^2}dx \right.$$
$$\left. + 2\mathrm{sign}(\xi)\int_{\frac{\eta\cdot\mathrm{sign}(\xi)}{|\xi|}}^{\eta\cdot\mathrm{sign}(\xi)} \frac{x^k}{1+x^2}\,dx\right).$$

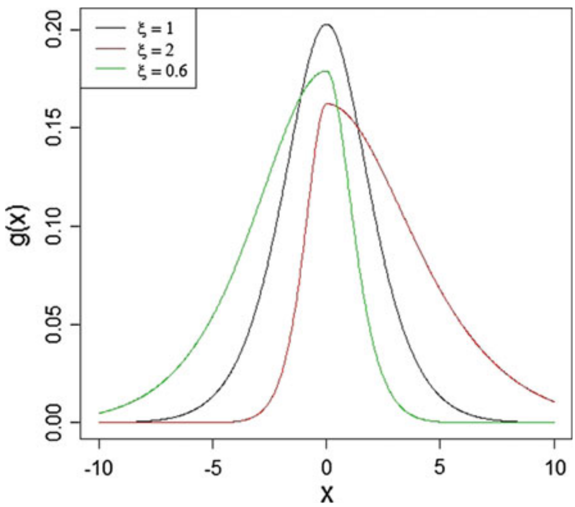
Finally, we have the raw moments for $k = 1, 2, 3, 4$ for $|\xi| \geq 1$.

$$\mu = \frac{\mathrm{sign}(\xi)}{2\arctan(\eta)}\left[\frac{\mathrm{AC}\left(\frac{\eta}{|\xi|}\right)}{\arctan(\eta)} + \ln\left(\frac{\xi^2(\eta^2+1)}{\eta^2+\xi^2}\right)\right],$$
$$\mu_2' = \frac{1}{\arctan(\eta)}(\eta - \arctan(\eta)),$$
$$\mu_3' = \frac{\mathrm{sign}(\xi)}{2\arctan(\eta)}\left[\frac{(\eta^2+1)\arctan(\eta\xi) - \eta\xi}{\xi^2} - \arctan(\eta)AC\left(\frac{\eta}{|\xi|}\right)\right.$$
$$\left. + \ln\left(\frac{\eta^2+\xi^2}{\xi^2(\eta^2+1)}\right) + \eta^2 - \left(\frac{\eta}{\xi}\right)^2\right],$$
$$\mu_4' = \frac{1}{\arctan(\eta)}\left(\frac{\eta^3}{3} - \eta + \arctan(\eta)\right).$$

32.3.2 Asymmetric Cauchy-Gaussian Distribution

The Asymmetric Cauchy-Gaussian can be generated as the normalized the product of the Cauchy and normal distributions:

Fig. 32.8 AGC for various ξ with η at 5



$$f(x) = \frac{1}{\omega(\eta)} \times \frac{\exp\left(-\frac{1}{2}\left(\frac{x}{\eta}\right)^2\right)}{1+x^2},$$

where $\omega(\eta) = \pi e^{\frac{1}{2\eta^2}}\left(1 - \Phi\left(\eta^{-1}\right)\right)$, where $\Phi(x)$ is the standard normal CDF (Fig. 32.8).

Now consider the Asymmetric Cauchy-Gaussian distribution (ACG) defined using the inverse scale factor method as

$$g(x) = \frac{2}{(\xi+\xi^{-1})\omega(\eta)} \frac{\exp\left(-\frac{1}{2}\left(\frac{x\xi^{-\mathrm{sign}(x)}}{\eta}\right)^2\right)}{1+x^2}.$$

Due to heavy computations, the moments of the AGC distribution, will be evaluated numerically in the next section.

32.3.3 Asymmetric Truncated Cauchy-Cosine Distribution

To overcome the jump at the boundaries of the ATC, we consider next, the product of the Cauchy distribution and of the cosine function over $\left[-\frac{\pi}{2}, \frac{\pi}{2}\right]$. We obtain the truncated Cauchy-Cosine distribution whose density is given below:

$$f(x) = \frac{1}{\lambda(\eta)} \frac{\cos\left(\frac{x}{\eta}\right)}{1+x^2} \mathbf{1}\left(-\frac{\pi}{2} < \frac{x}{\eta} < \frac{\pi}{2}\right),$$

where $\lambda(\eta) = \int_{-\frac{\eta\pi}{2}}^{\frac{\eta\pi}{2}} \frac{\cos\left(\frac{x}{\eta}\right)}{1+x^2}\, dx$.

We induce skewness using the inverse scale factor method to obtain the asymmetric truncated Cauchy-Cosine distribution (ATCC):

$$g(x) = \frac{2}{\lambda(\eta)(\xi + \xi^{-1})} \frac{\cos\left(\frac{x}{\eta}\xi^{-sign(x)}\right)}{1 + \left(x\xi^{-sign(x)}\right)^2} \mathbf{1}\left(-\frac{\pi}{2} < \frac{x}{\eta}\xi^{-sign(x)} < \frac{\pi}{2}\right).$$

The first four raw moments of the ATCC are as follows (Fig. 32.9).

$$\mu = \frac{\xi^2 - \xi^{-2}}{\xi + \xi^{-1}},$$
$$\mu_2' = \frac{\xi^3 + \xi^{-3}}{\xi + \xi^{-1}} \left(\frac{2\eta}{\lambda(\eta)} - 1\right),$$
$$\mu_3' = \frac{\xi^4 - \xi^{-4}}{\xi + \xi^{-1}} \left(\frac{\eta^2}{\lambda(\eta)} (\pi - 2) - 2\tilde{m}_1\right),$$

where $\tilde{m}_1$ is the first half-moment of f.

$$\mu_4' = \frac{\xi^5 + \xi^{-5}}{\xi + \xi^{-1}} \left(\frac{\eta^3}{2\lambda(\eta)}(\pi^2 - 8) - \left(\frac{2\eta}{\lambda(\eta)} - 1\right)\right).$$

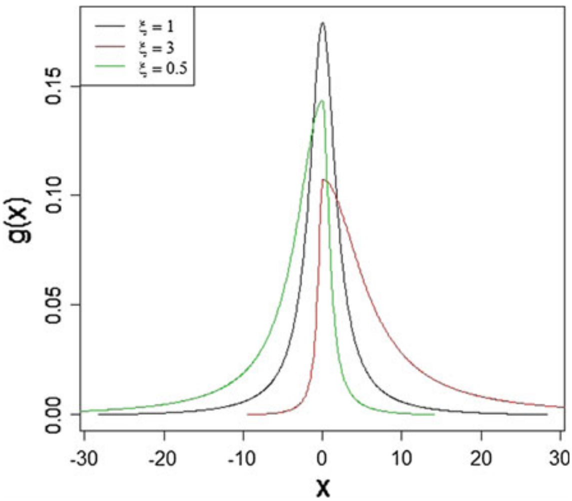


Fig. 32.9 ATCC for various ξ with $\eta = 9$ and $s = 2$

32.4 Comparing the Distributions

We use the existence condition for the skweness and kurtosis as a criterion to compare the flexibility of the distributions. For each of the distributions, we compare the area of attainable skewness and kurtosis. The "best" distribution would be the one that covers as much as possible of the maximal domain contained within the parabola $s^2 \leq \kappa - 1$. The boundaries of such areas are shown in Fig. 32.10 for each of the distributions presented in Sect. 32.3.

Figure 32.10 shows that the set of attainable skewness-kurtosis for each of the three distributions is a subset of the theoretical maximum. The ATC distribution produces the largest such domain with ATCC as a close second. The boundary of AGC gets closer to that of ATC for large values of η or ξ. Both ATC distributions, corresponding to each of the two asymmetry-inducing methods, produce the same skewness-kurtosis boundary. The infimum kurtosis of ATC is equal to 1.8, which is the kurtosis of the symmetric uniform distribution and it is attained when η approaches infinity. The infimum kurtosis for AGC is 3, which corresponds to the kurtosis of a normal distribution achieved when η is infinite.

Figure 32.11 shows that the domain of ATC is much larger than that of Student and Pearson IV distributions. This is also the case when these distributions are compared to the ACG and ATCC. Note that the minimum kurtosis for Student and Pearson IV is equal to 3, since the normal distribution is a special case of both Student and Pearson IV distribution.

Next, we explore the relationship between the parameters η and ξ, and the skewness and kurtosis. Figure 32.12a shows that the attainable values of skewness get larger with η. Figure 32.12b shows that, for any ξ, the kurtosis is a strictly increasing function of η. This implies that any attainable pair of values of the skewness and

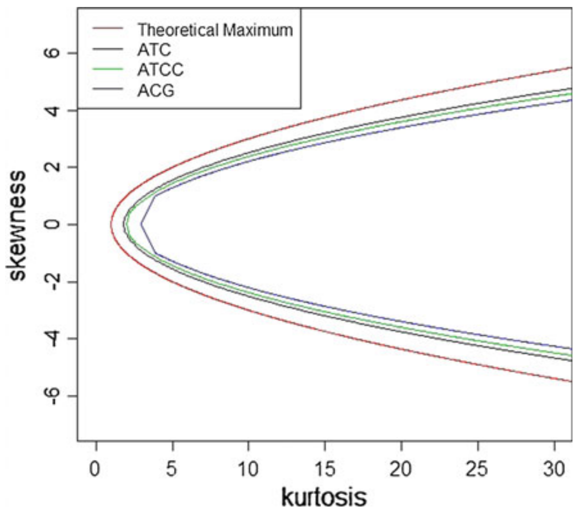


Fig. 32.10 Domain of existence for the ATC, AGC, and ATCC

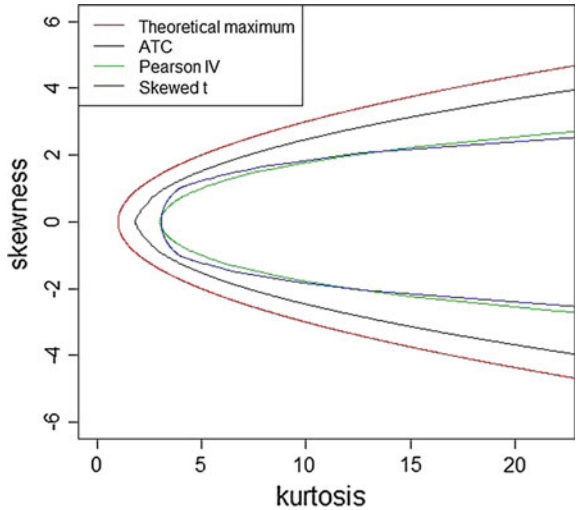


Fig. 32.11 Domain of existence for the ATC when compared to the skewed Student *t* and Pearson IV

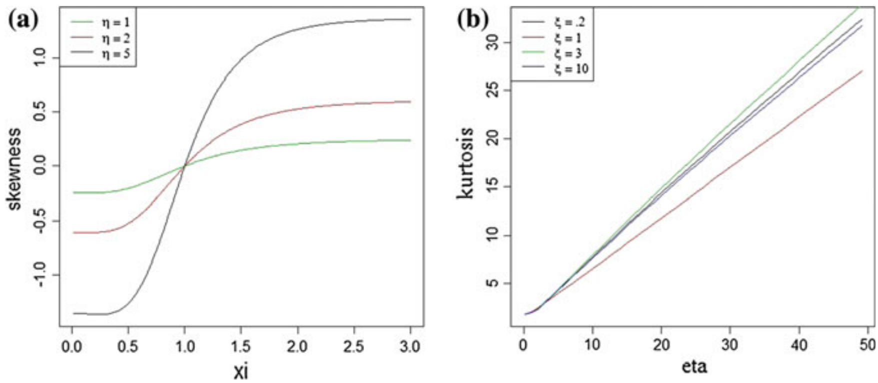


Fig. 32.12 Skewness and Kurtosis as functions of η and ξ

kurtosis can be obtained through the ATC by finding the right distribution parameters. This property is shared by AGC and ATCC as well.

32.5 Conclusion

In this study, we presented a novel method for generating new distributions by convolving the characteristic functions of classical distributions. This was achieved by introducing a parameter that controls the distribution's tail weight. We used this method to derive new flexible distributions that outperform Student and Pearson IV distributions when it comes to modeling financial data.

The nature of the proposed method of generating distributions allows it also to generate survival models either by convolving characteristic functions or by convolving Fourier transforms of survival functions. This would be helpful in deriving new accelerated failure or proportional hazard models using more flexible baseline survival functions. The new distributions can also be used to fit the innovations in time series models. The methodology can be easily extended to generate new multivariate distributions.

References

1. Cont R (2001) Empirical properties of asset returns: stylized facts and statistical issues. Quant Financ 1:223–236
2. Campbell JY, Lo AWC, MacKinlay AC et al (1997) The econometrics of financial markets, vol 2. Princeton University Press, Princeton
3. Jondeau E, Poon SH, Rockinger M (2007) Financial modeling under non-Gaussian distributions. Springer Science & Business Media, London
4. Stieltjes T (1894) Recherches sur les fractions continues. Annales de la faculte des sciences de Toulouse 8:1–22
5. Hausdorff F (1921) Summationsmethoden und momentfolgen. i. Mathematische Zeitschrift 9(1–2):74–109
6. Hausdorff F (1921) Summationsmethoden und momentfolgen. ii. Mathematische Zeitschrift 9(3):280–299
7. Hamburger H (1920) Über eine erweiterung des stieltjesschen momentenproblems. Mathematische Annalen 81(2–4):235–319
8. Widder DV (1946) The laplace transform. Princeton University Press, Princeton
9. Gallant AR, Tauchen G (1989) Seminonparametric estimation of conditionally constrained heterogeneous processes: Asset pricing applications. Econometrica J Econ Soc 57:1091–1120
10. Johnson NL, Kotz S, Balakrishnan N (1994) Continuous univariate distributions. Wiley, New York
11. Theodossiou P (1998) Financial data and the skewed generalized t distribution. Manag Sci 44(12–part–1):1650–1661
12. Jondeau E, Rockinger M (2001) Gram-charlier densities. J Econ Dyn Control 25(10):1457–1483
13. Hansen BE (1994) Autoregressive conditional density estimation. Int Econ Rev 35:705–730
14. Jondeau E, Rockinger M (2003) Conditional volatility, skewness, and kurtosis: existence, persistence, and comovements. J Econ Dyn Control 27(10):1699–1737
15. Theodossiou P (1998) Financial data and the skewed generalized t distribution. Manag Sci 44:1650–1661
16. Lee TK, Tse YK (1991) Term structure of interest rates in the singapore asian dollar market. J Appl Econom 6(2):143–152
17. Azzalini A, Dalla Valle A (1996) The multivariate skew-normal distribution. Biometrika 83(4):715–726

Chapter 33
Fast Multi-objective Hybrid Evolutionary Algorithm for Flow Shop Scheduling Problem

Wenqiang Zhang, Jiaming Lu, Hongmei Zhang, Chunxiao Wang and Mitsuo Gen

Abstract In this paper, a fast multi-objective hybrid evolutionary algorithm (MOHEA) is proposed to solve the bi-criteria flow shop scheduling problem with the objectives of minimizing makespan and total flow time. The proposed algorithm improves the vector evaluated genetic algorithm (VEGA) by combing a new sampling strategy according to the Pareto dominating and dominated relationship-based fitness function. VEGA is good at searching the edge region of the Pareto front, but it has neglected the central area of the Pareto front, and the new sampling strategy prefers the center region of the Pareto front. The hybrid sampling strategy improves the convergence performance and the distribution performance. Simulation experiments on multi-objective test problems show that, compared with NSGA-II and SPEA2, the fast multi-objective hybrid evolutionary algorithm is better in the two aspects of convergence and distribution, and has obvious advantages in the efficiency.

Keywords Flow shop scheduling · Hybrid evolutionary algorithm · Vector evaluated genetic algorithm · Multi-objective optimization

W. Zhang (✉) · J. Lu · H. Zhang · C. Wang
Henan University of Technology, Zhengzhou, People's Republic of China
e-mail: zhangwq@haut.edu.cn

W. Zhang
Key Laboratory of Grain Information Processing and Control, Ministry of Education, Zhengzhou, China

M. Gen
Fuzzy Logic Systems Institute, Fukuoka, Japan

M. Gen
Tokyo University of Science, Katsushika, Japan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_33

33.1 Introduction

Scheduling problem is to allocate scarce resources to different tasks at the same time under certain constraints. It is a decision-making process, which aims to optimize one or more objectives [1]. Flow shop scheduling problem (FSP) is a typical example in the job shop scheduling problem and belongs to the NP-hard problem [2]. The purpose of FSP is to find an optimal solution under certain constraints, so as to realize the effective allocation and utilization of resources.

In recent years, FSP has been widely studied and discussed. Amin et al. [3] proposed a new mathematical model for the hybrid FSP and calculated the makespan with a new heuristic algorithm. Gao et al. [4] proposed a hybrid heuristic algorithm, reducing the total flow time of the no wait FSP. Athanasios [5] proposed a new hybrid parallel genetic algorithm to solve the FSP, improving the crossover and mutation operator of genetic algorithm. Zhang and Gu used a discrete artificial bee colony algorithm for the FSP with intermediate buffers in order to minimize the maximum completion time [6]. Gu et al. [7] improved adaptive particle swarm optimization algorithm for solving the minimum makespan problem of FSP. Pugazhenthi and Xavior [8] proposed a new exponential distribution technique to find an optimum sequence for the FSP. Sun et al. [9] proposed a new heuristic, named SDH heuristic, for solving the no-wait FSP with the objective to minimize total flow time. However, most of above studies prefer single objective rather than multi-objective. The multi-objective FSP will meet the actual demand. Zhu et al. [10] improved the genetic algorithm by combining Grey Entropy Parallel Analysis method to solve the multi-objective FSP. Liu et al. [11] used a niche particle swarm algorithm to solve the hybrid multi-objective FSP under the satisfaction and the date of delivery. Liu et al. [12] applied the NSGA-II to the FSP with the minimum of makespan and the lowest cost. Chen and Zhou [13] proposed an improved food chain algorithm for the FSP with multiple objectives of minimizing makespan and total tardiness. Zhang and Huang [14] proposed a hybrid genetic algorithm by combing the advantage of the particle swarm optimization for the multi-objective flow shop. Although above studies focus on the multi-objective, they didn't consider the efficiency of the algorithm.

The advantage of evolutionary algorithm is that it can carry out the global search among populations, and it is very effective to search for the optimal solution set of Pareto. Multi-objective Evolutionary algorithm (MOEA) is a hot research topic in the field of evolutionary computation, which is used to solve multi-objective optimization problems.

Vector evaluated genetic algorithm (VEGA) is the first MOEA [15]. The feature of VEGA makes it a strong ability to converge to the edge of the Pareto front. However, the diversity of VEGA is not very good because of its choice bias. NSGA-II [16] and SPEA2 [17] has been proved to be able to get good results in solving multi-objective optimization problems. However, the rank sorting and crowding distance increase NSGA-II's CPU time. Because of the strategy of the raw fitness and the distance calculation, SPEA2 takes more CPU time than NSGA-II. It is worth mentioning that due to the difference of the archive updating mechanism, SPEA2 has better distribution performance than NSGA-II when there are a lot of non-dominated solutions.

In this paper, for improving the convergence and the distribution and reducing the computing time at the same time, we proposed a multi-objective hybrid evolutionary algorithm (MOHEA) to solve multi-objective FSP. Based on the sampling strategy of VEGA, the proposed MOHEA adds a new sampling strategy according to a new Pareto dominating and dominated relationship-based fitness function (PDDR-FF) in which we revised the hybrid sampling strategy-based multi-objective evolutionary algorithm (HSS-MoEA) [18]. According to PDDR-FF, the individual with different domination number has different fitness value. The individuals in the central area of Pareto front will have smaller fitness than the individuals in the marginal region. The mixed sampling mechanism not only improves the convergence rate of the algorithm, but also enhances the performance of the algorithm.

The structure of this paper is as follows: the second part describes and constructs the mathematical model of the FSP; the MOHEA is described in detail in the third part; the fourth part gives the numerical simulation experiments and the results are analyzed and discussed; the conclusion and the prospect of the future work are given in the fifth part.

33.2 Problem Description

Flow shop scheduling can be described as follows: each job from the set $J = \{J_1, J_2, \ldots, J_n\}$ should be processed on the m machines from set $M_1, M_2, \ldots, M_m$. Assuming that the jobs are processed as the indexed sequential of the machines, O_{ji} is defined as the ith operation of the job J_i and the processing time of O_{ji} on the machine M_i is p_{ji}. The purpose of the FSP is to find a set of non-dominated solutions set, minimizing the makes pan and total flow time (TFT) simultaneously, for the decision makers. Generally, FSP is assumed as follows:

(1) a job can only be processed in one machine at the same time;
(2) a machine can only process one job at the same time;
(3) a process can't stop once started;
(4) the processing sequence of the job on each machine is the same.

Let $\pi = (\pi\,(1)\,, \pi\,(2)\,, \cdots, \pi\,(n))$ be a set of processing sequences for the job, where π_a is the ath job of the sequence π. U represents all possible process combinations, and $\pi \in$ U. $C^i_{\pi(j)}$ is the completion time of job π_j on the machine M_i and t_{ji} is the completion time of operation O_{ji} on the machine M_i. If operation O_{ji} is processed on the machine M_i, $x_{ji} = 1$, otherwise, $x_{ji} = 0$; if operation O_{ji} is processed before O_{kh}, $y_{jikh} = 1$, otherwise, $y_{jikh} = 0$. The mathematical formulation of FSP can be described as below:

$$\begin{aligned} &C_{\pi(1)}^{1} = p_{\pi(1)\ 1} \\ &C_{\pi(1)}^{i} = C_{\pi(1)}^{i-1} + p_{\pi(1)\ i} \\ &C_{\pi(j)}^{1} = C_{\pi(j-1)}^{1} + p_{\pi(j)\ 1} \\ &C_{\pi(j)}^{i} = \max\left\{C_{\pi(j-1)}^{i}, C_{\pi(j)}^{i-1}\right\} + p_{\pi(j)\ i} \\ &j = 2, 3, \ldots, n,\ \ i = 2, 3, \ldots, m. \end{aligned} \tag{33.1}$$

The bi-criteria optimization objectives can be formalized as:

$$\min\ C_{\max}(\pi) = C_{\pi(n)}^{m} \tag{33.2}$$

$$\min\ F(\pi) = \sum\nolimits_{i=1}^{n} F(\pi(i)) = \sum\nolimits_{i=1}^{n} C_{\pi(i)}^{m} \tag{33.3}$$

$$s.t.\ \left(t_{kh} - p_{kh} - t_{ji}\right) x_{ji} x_{kh} y_{jikh} > 0, \forall (j, i), (k, h) \tag{33.4}$$

$$y_{jiji} = 0, \forall (j, i) \tag{33.5}$$

$$\sum_{i=1}^{m} x_{ji} = 1, \forall (j, i) \tag{33.6}$$

$$\sum_{j=1}^{n} x_{ji} = 1, \forall (j, i) \tag{33.7}$$

$$y_{jikh} \in \{0, 1\}, \forall (j, i)(k, h) \tag{33.8}$$

$$x_{ji} \in \{0, 1\}, \forall (j, i) \tag{33.9}$$

$$t_{ji} \geq p_{ji} \geq 0, \forall (j, i) \tag{33.10}$$

The completion time of each job is represented by the Eq. (33.1). The Eq. (33.2) defines the minimization of makespan. From the Eq. (33.1) it can be seen that the makespan is the completion time of the last job $\pi(n)$ on the machine M_m, for the sequence π, decided by $C_{\pi(n)}^{m}$. The minimization of total flow time is the total completion time of all the jobs, which is defined by the Eq. (33.3). The Eq. (33.4) specifies the processing sequence on each machine. The Eq. (33.5) ensures the feasibility of the process sequence. Uniqueness constraint of the job is the Eq. (33.6). The Eq. (33.7) is the uniqueness constraint of the machine. The Eqs. (33.8), (33.9) and (33.10) define non negative condition.

33.3 Multi-objective Hybrid Evolutionary Algorithm

33.3.1 PDDR-FF

In this paper, a new fitness function based on a new Pareto dominating and dominated relationship-based fitness function (PDDR-FF) is proposed to evaluate the fitness of each individual. The fitness function value of an individual is calculated by the following function:

$$\text{eval}\,(S_i) = B\,(S_i) + \frac{1}{D\,(S_i) + 1}, \tag{33.11}$$

where $B(S_i)$ is the number of individuals dominating, which is defined as the Eq. (33.12):

$$B(S_i) = |\{S_j | S_j \prec S_i, j = 1, 2, \ldots, \text{popSize}\}, | \tag{33.12}$$

where $D(S_i)$ is the number of individuals dominated by as defining the Eq. (33.13), popSize is the size of the population.

$$D(S_i) = \left|\left\{S_j \left| S_i \prec S_j, j = 1, 2, \ldots, \text{popSize}\right.\right\}\right| \tag{33.13}$$

The smaller the PDDR-FF value means that the more individuals dominated by S_i and the less individuals dominate S_i. Therefore, the smaller the PDDR-FF value, the better. And besides, PDDR-FF can also set clear differences between the non-dominated individual and the dominant individual. If an individual is a non-dominant individual, the fitness function value is not more than 1. Furthermore, even if it is not a dominant individual, the individual with different numbers of domination is given a different fitness function values. It is obvious that the fitness function value (close to 0) of the non-dominated individuals locating near the central area of the Pareto front having big domination area is smaller than the value (close to 1) of the individual in the edge region.

33.3.2 MOHEA

The sampling strategy based on PDDR-FF has the tendency to converge to the Pareto front, but the convergence of the edge region is not so good. Only using the PDDR-FF based sampling strategy can cause the distribution performance of the imbalance. Compared to the central area of Pareto front, the sampling strategy of VEGA is more preferred than the edge region, and the single use of VEGA sampling can also lead to the problem of the distribution performance. Therefore, combining these two methods can improve the overall performance of the algorithm and reduce the computation time. The specific step process of MOHEA is as follows:

(1) Initialization of algorithm parameters: The size of the population: popSize, the size of archive: archiveSize, the maximum number of calculation: max-Evaluations.

(2) Creating initial population and initial archive.

(3) Loop steps (4)C(7) until the termination condition is satisfied: The number of the calculation achieves the maximum.

(4) Selection (sampling strategy of VEGA)Use the VEGA sampling strategy to select good individuals as a part of the mating pool. For the two objectives of FSP, get the ascending order of all the individuals in the population according to the single objective 1 and select $|P(t)|/2$ individuals with replacement into the sub-population 1 in order. In a similar way, considering objective 2 without objective 1, select $|P(t)|/2$ individuals with replacement into the sub-population 2 in the ascending order according to the value of objective 2.

(5) Generation of the mating pool: Mix the sub-populations and $A\ (t)$ to form the mating pool. In the mating pool, sub-population 1 stores the excellent individuals for the objective 1, and sub-population 2 keeps the excellent individuals for the other objective. The individuals with good PDDR-FF value are stored in $A\ (t)$. Since there are two objectives in this FSP, the size of these two sub populations and archive are set to the half size of the population. As a result, there are three parts in the mating pool, 1/3 of the individuals serve the objective 1, 1/3 of the individuals tend to the objective 2 and the remaining individuals obeys both the two objectives.

(6) Genetic operations: According to the selection operator, two individuals are selected from the mating pool as the parent and the new generation $P\ (t+1)$ is produced after genetic operations (crossing and mutation).

(7) The updating of the archive (sampling strategy based on PDDR-FF): Mixing the new generation $P\ (t+1)$ and the archive to form the temp population $A^{'}\ (t)$. Calculate the fitness function value of all individuals in the population, according to the ascending order and individuals with the smallest of the $|A\ (t)|$ values are chosen as $A\ (t+1)$.

(8) Output the archive $A\ (t)$.

33.4 Experiments and Discussion

The data of the experiments of this study comes from FSP test set proposed by Taillard in 1993 [19]. MOHEA, SPEA2 and NSGA-II are tested in the same conditions. The conditions of the computer are: Core 2 CPU with 2.8 GHz clock, 2G ram, Windows XP. All the parameters are: population size, 100; maximum generation, 2000; crossover probability, 0.40; mutation probability, 0.80. The archive size of MOHEA is halt of the population size, 50, while the archive size of NSGA-II and SPEA2 are same as the population size, 100. The three algorithms use the same selection, crossover, mutation but different fitness and archive mechanisms. The partially smapped crossover (PMX) and the swap mutation are adopted in this experiment [20]. Compare the results of MOHEA, NSGA-II, and SPEA2 for running 30 times.

The sampling strategy of MOHEA based on PDDR-FF can be tested by analyzing the experimental data in a test problem. The performance measures coverage C and spacing SP are adopted [21, 22]. C is for the convergence performance and SP is

Table 33.1 C

Problem	Job	Machine	C(SPEA2, MOHEA)	C(MOHEA, SPEA2)	C(NSGA-II, MOHEA)	C(MOHEA, NSGA-II)
FSP01	20	5	$6.44e - 011.5e - 01$	$9.66e - 018.2e - 02$	$6.06e - 012.2e - 01$	$9.74e - 011.0e - 01$
FSP02	20	10	$5.75e - 011.6e - 01$	$9.22e - 011.2e - 01$	$6.09e - 012.0e - 01$	$9.47e - 019.5e - 02$
FSP03	20	20	$7.39e - 011.3e - 01$	$9.60e - 013.8e - 02$	$7.65e - 011.1e - 01$	$9.29e - 015.2e - 02$

Table 33.2 SP

Problem	Job	Machine	SPEA2	NSGA-II	MOHEA
FSP01	20	5	$2.84e + 017.2e + 00$	$2.74e + 017.6e + 00$	$1.12e + 014.5e + 00$
FSP02	20	10	$3.29e + 011.3e + 01$	$3.61e + 012.3e + 01$	$2.08e + 011.8e + 01$
FSP03	20	20	$2.44e + 019.5e + 00$	$1.86e + 015.3e + 00$	$1.31e + 016.8e + 00$

Table 33.3 CPU times

Problem	Job	Machine	SPEA2	NSGA-II	MOHEA
FSP01	20	5	$7.92e + 046.8e + 03$	$1.29e + 042.6e + 03$	$8.29e + 039.9e + 02$
FSP02	20	10	$8.92e + 047.6e + 03$	$1.25e + 042.1e + 03$	$8.73e + 036.9e + 02$
FSP03	20	20	$6.57e + 043.2e + 03$	$1.38e + 041.3e + 03$	$9.23e + 039.8e + 02$

for the distribution performance. The mean and variance of the CSP and CPU times by MOHEA, NSGA-II and SPEA2 are shown as Tables 33.1, 33.2 and 33.3 and the corresponding box-and -whisker plots are show as Fig. 33.1. It is easy to see that MOHEA is better than NSGA-II and SPEA2 in the performance of convergence and distribution. On the other hand, the speed of MOHEA is faster than NSGA-II and SPEA2.

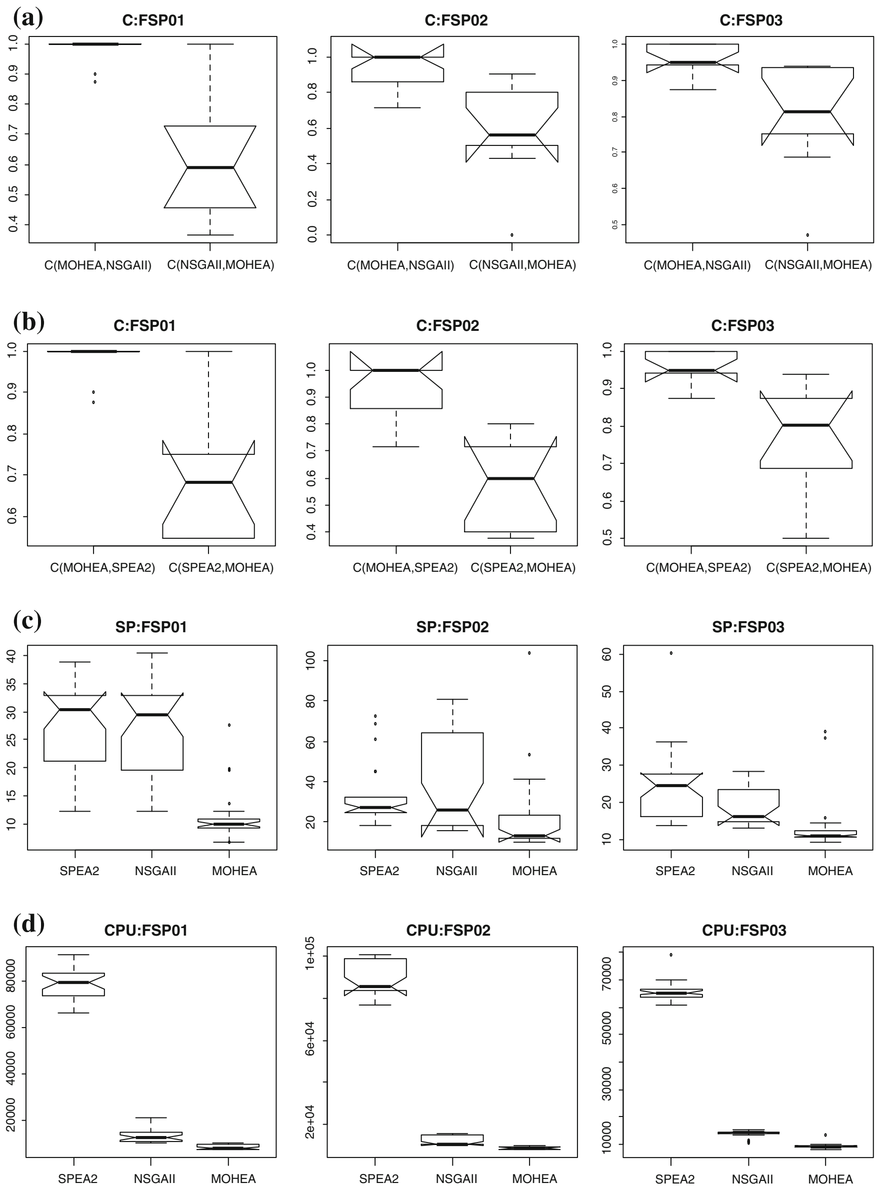


Fig. 33.1 C, SP and CPU times by SPEA2, NSGA-II and MOHEA

33.5 Conclusions

In this paper, a fast multi-objective hybrid evolutionary algorithm (MOHEA) is proposed according to multi-objective flow shop scheduling problem (FSP), considering minimization of makespan and total flow time. We proposed a new Pareto dominating and dominated relationship-based fitness function (PDDR-FF) to evaluate individuals and combine the sampling strategy of VEGA. The sampling strategy of VEGA prefers the edge region of the Pareto front, while the sampling strategy based on PDDR-FF has the tendency to converge to the center region. The proposed algorithm with the hybrid sampling strategy can maintain the convergence and distribution performance simultaneously. The results of the experimental data show that MOHEA is outstanding in convergence and distribution performance and has obvious advantages in efficiency, comparing with NSGA-II and SPEA2.

Acknowledgments This research work is supported by the National Natural Science Foundation of China: No. U1304609, the Key Young Teacher Training Program of Henan University of Technology, the Fundamental Research Funds for the Henan Provincial Colleges and Universities: No. 2014YWQQ12, Research Funds for Key Laboratory of Grain Information Processing and Control (Henan University of Technology), Ministry of Education and the Grant-in-Aid for Scientific Research (C) of Japan Society of Promotion of Science (JSPS): No. 15K00357.

References

1. Pinedo M (2012) Scheduling: theory, algorithms, and systems. Springer Science & Business Media, New York
2. Gonzalez T, Sahni S (1978) Flowshop and jobshop schedules: complexity and approximation. Oper Res 26(1):36–52
3. Amin Z, Reza T, Khosro P (2012) Solving a new mathematical model for a hybrid flow shop scheduling problem with a processor assignment by a genetic algorithm. Int J Adv Manuf Technol 61(1–4):339–349
4. Gao K, Pan Q et al (2013) Effective heuristics for the no-wait flow shop scheduling problem with total flow time minimization. Int J Adv Manuf Technol 66(9–12):1563–1572
5. Spanos CA, Ponis TS, Tatsiopoulos IP et al (2014) A new hybrid parallel genetic algorithm for the job-shop scheduling problem. Int Trans Oper Res 21(3):479–499
6. Zhang S, Gu X (2015) An effective discrete artificial bee colony algorithm for flow shop scheduling problem with intermediate buffers. J Central South Univ 22:3471–3484
7. Gu W, Tang D, Zheng K (2014) Solving job-shop scheduling problem based on improved adaptive particle swarm optimization algorithm. Trans Nanjing Univ Aeronaut Astronaut 31(5):559–567
8. Pugazhenthi R, Xavior MA (2014) A characteristic study of exponential distribution technique in a flowshop using taillard benchmark problems. Pak Acad Sci 51:187–192
9. Sun Q, Gao K, Li H (2011) A heuristic for the no-wait flow shop scheduling optimization. In: 2011 IEEE 2nd international conference on computing, control and industrial engineering (CCIE), vol 1. IEEE, pp 192–195
10. Zhu G, He L (2015) Multi-objective flow shop schedule based on grey entropy parallel analysis optimization algorithm. Comput Eng 41:165–170
11. Liu Z, Ma L, Luo J (2015) Multi-objective problem of schedule for hybrid flow shop based on niching particle swarm optimization. Machinery Design & Manufacture pp 255–258

12. Liu S, Li X (2015) Solving the multi objective scheduling problem of hybrid flow shop with nsga-ii. Ind Econ Rev 6:91–99
13. Chen K, Zhou X (2015) Improved food chain algorithm for multi-objective permutation flow shop scheduling. China Mech Eng 360:348–353
14. Zhang Z, Huang M (2015) Solving hybrid flow-shop scheduling based on improved multi-objective genetic algorithm. Comput Appl Softw 314:291–293
15. Schaffer JD (1985) Multiple objective optimization with vector evaluated genetic algorithms. In: Proceedings of the 1st international conference on genetic algorithms, L. Erlbaum Associates Inc., pp 93–100
16. Deb K, Pratap A et al (2002) A fast and elitist multi-objective genetic algorithm: Nsga-II. IEEE Trans Evolu Comput 6:182–197
17. Zitzler E, Laumanns M, Thiele L (2002) SPEA2: improving the strength pareto evolutionary algorithm. In: Evolutionary methods for design, optimization, and control with applications to industrial problems, Athens: EUROGEN, pp 95–100
18. Zhang W, Gen M, Jo J (2014) Hybrid sampling strategy-based multiobjective evolutionary algorithm for process planning and scheduling problem. J Intell Manuf 25(5):881–897
19. Taillard E (1993) Benchmarks for basic scheduling problems. Eur J Oper Res 64(2):278–285
20. Goldberg D, Lingle RJ (1985) Alleles, loci, and the traveling salesman problem. In: Proceedings of the first international conference on genetic algorithms and their applications. Lawrence Erlbaum Associates, Publishers, pp 154–159
21. Schott J (1995) Fault tolerant design using single and multicriteria genetic algorithm optimization. Technical report, DTIC Document
22. Zitzler E, Thiele L (1999) Multiobjective evolutionary algorithms: a comparative case study and the strength pareto approach. IEEE Trans Evol Comput 3(4):257–271

Chapter 34
A Warfare Inspired Optimization Algorithm: The Find-Fix-Finish-Exploit-Analyze (F3EA) Metaheuristic Algorithm

Ali Husseinzadeh Kashan, Reza Tavakkoli-Moghaddam and Mitsuo Gen

Abstract This paper introduces a new evolutionary algorithm for continuous optimization which mimics the targeting process of selecting objects or installations to be destroyed in warfare. The algorithm performs main steps of Find, Fix, Finish, Exploit and Analyze (F3EA) in an iterative manner. For the Find step, a new selection operator is introduced which mimics the object detection process followed by the radar devices. It is justified that how the Fix step can be modeled as a single variable optimization problem to scan the path between the two individuals to determine the precise location of a local optimum. During the Finish step, which is a mutation stage, it is assumed that an artificial missile is launched from the current position toward the position selected via the Find step. We use from the motion equations of Physics which govern the path traveled by the missile to generate the new solutions within the search space. The Exploit step tries to take over opportunities presented by the generated solution during the Finish step. Finally in the Analyze step, if the resultant solution of the Exploit step produces a better function value, it enters into the population or updates the global best solution. Performance of the proposed algorithm is tested on a collection of classic functions. Results demonstrate that the algorithm is very efficient and effective.

Keywords Numerical optimization · Metaheuristics · F3EA targeting process · Radar range equation · Projectile motion

---

A.H. Kashan (✉)
Department of Industrial and Systems Engineering, Tarbiat Modares University, Tehran, Iran
e-mail: a.kashan@modares.ac.ir

R. Tavakkoli-Moghaddam
School of Industrial Engineering, University of Tehran, Tehran 1417466191, Iran

M. Gen
Fuzzy Logic Systems Institute (FLSI), Iizuka Fukuoka, Japan

M. Gen
Tokyo University of Science, Tokyo, Japan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_34

34.1 Introduction

Very often techniques developed within artificial intelligence (AI) end up being very efficient optimization tools. This has happened, for example, with metaheuristics. The term "metaheuristic" is used for a general algorithmic framework, with relatively few modifications required to solve different optimization problems, which combines rules and randomness while imitating natural phenomena. In this paper a new metaheuristic algorithm, called F3EA, is introduced based on imitating an emerging approach to targeting process in warfare. Some physical theories which govern the performance of battlefield weaponry are also employed to develop the equations of the Find-Fix-Finish-Exploit-Analyze (F3EA) algorithm.

The F3EA algorithm specifically mimics the targeting process of selecting objects or installations to be attacked, taken, or destroyed in warfare. The emphasis of targeting is on identifying resources (targets) the enemy can least afford to lose or that provide him with the greatest advantage, then further identifying the subset of those targets which must be acquired and engaged to achieve friendly success. General Stanley A. McChrystal wrote in 2014 about a targeting cycle called "F3EA" used in the Afghanistan and Iraq wars, which stands for [1]:

- Find: describes the process through which targets and their elements (person or location) are identified.
- Fix: is the process which allows prepared targets to be monitored in preparation for actioning.
- Finish: is the term describing the process by which targets are actioned.
- Exploit: describes the process by which opportunities presented by the target effect are identified.
- Analyze: is an assessment phase that pertains to the results of attacks on targets used to restart the F3EA cycle to identify further targeting opportunities.

Although the metaphor of the F3EA algorithm comes from targeting process in warfare as described above, it uses the underlying theories of Physics of radar and projectile motion in the Find and Finish steps, respectively. The info graph of F3EA algorithm comes in Fig. 34.1. In the remainder of the paper we present the mathematical model of different steps of the F3EA algorithm. However, we present the Fix step right after we model other steps, for the reason that the Fix step can perform as an add-on module independently. In what follows, we assume that $f(\mathbf{X} = [x_1, x_2, \ldots, x_n])$ is an n variable numerical function that should be minimized over the n dimensional decision space defined by $x_{\min,d} \le x_d \le x_{\max,d}$, $d = 1, \ldots, n$. Recall that and we are seeking the global minimum of f that is, finding $\mathbf{X}^* \in \mathrm{R}^n$ such that $f(\mathbf{X}^*) \le f(\mathbf{X}), \forall \mathbf{X} \in \mathrm{R}^n$.

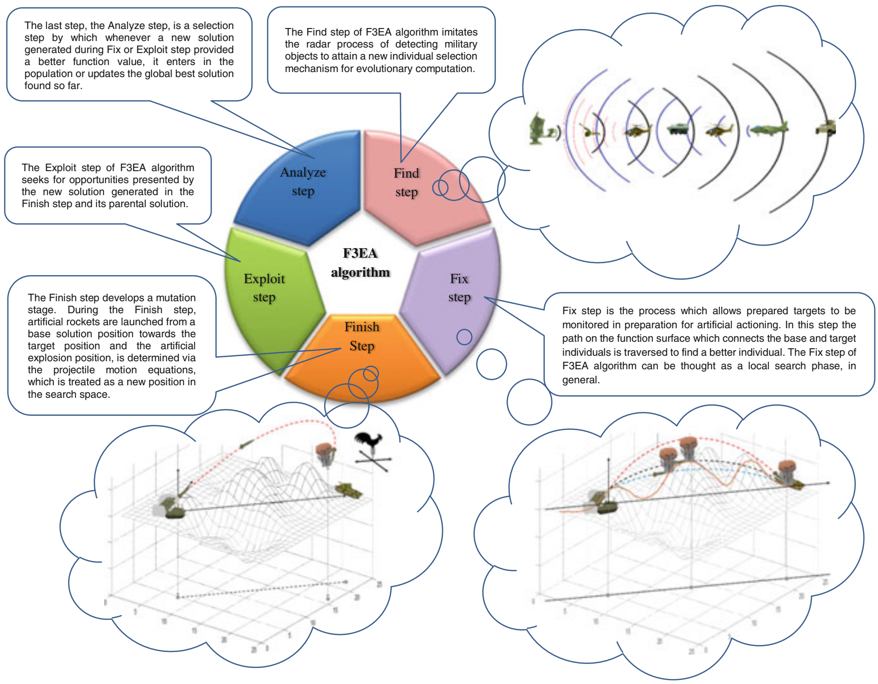


Fig. 34.1 The info graph of F3EA algorithm

34.2 Modeling the "Find" Step of F3EA Algorithm

Radar is an electromagnetic system for the detection of reflecting objects. The basic operation of primary radar is based on transition of the short duration pulses of radio-frequency electromagnetic energy, via transmitter device and its reflection from the reflecting object. A small portion of the reflected energy, returns to the radar set and is picked up by the receiver device to determine the direction and distance of the reflecting object.

One of the simplest equations of radar theory is the radar range equation which was developed during World War II to permit analysis of radar system performance. The original radar equation was first published by Norton and Omberg [7] of the U.S. Naval Research Laboratory. The objective of the radar equation is to calculate the maximum range ($R_{\max}$) at which the desired detection performance is achieved by a specific radar set, target and environmental parameters. The maximum radar detection range for a single antenna system is as follows:

$$R_{\max} = K_{\text{Radar}} \sqrt[4]{\sigma}, \tag{34.1}$$

where $K_{\text{Radar}} = \sqrt[4]{pGA/(4\pi)^2 S_{\min}}$ in which p is the peak power transmitted by the radar, G is the antenna gain of the radar, A is the antenna's aperture, $S_{\min}$ is the minimum amount of received radar signal that we can have and still detect the signal. In Eq. (34.1), the radar range equation is influenced by two factors, namely K_{Radar} which is dependent to radar engineering design and specifications and σ which is the radar cross section of target. The amount of radiated power reflected back is determined by the radar cross section. The most important use of the radar range equation is the determination of the maximum range at which a target has a high probability of being detected by the radar.

Given the theory of maximum radar range equation, in this part we are going to imitate the radar process of detecting military objects to attain a new individual selection mechanism for evolutionary computation. In the proposed selection method which roles as the Find step in F3EA algorithm, each individual (except the ith one) in the population Π^t, in iteration t, is treated as an enemy's military facility. To generate a new solution from the ith individual parent solution in the population, we assume that the parent solution temporarily makes role as a radar device and all other individuals are assumed to be enemy's military facilities which may or may not be detected by the artificial radar (see Fig. 34.2). In this way, in the proposed selection mechanism, only an individual which is detectable by the artificial radar can be selected by which a new solution being generated during the Finish step. The measure of detectability is the function value.

With $\mathbf{P}_i^t$ we address either the ith individual in the population Π^t or its position in the search space. To generate a new solution from $\mathbf{P}_i^t$ (the parent solution) with the aid of $\mathbf{P}_j^t, \forall j = 1, \ldots, N_B, j \neq i$ (the jth individual), we assume that it makes role as an artificial radar with its maximum range, for detecting $\mathbf{P}_i^t$ equal to $R_{\max ij}^t$, peak

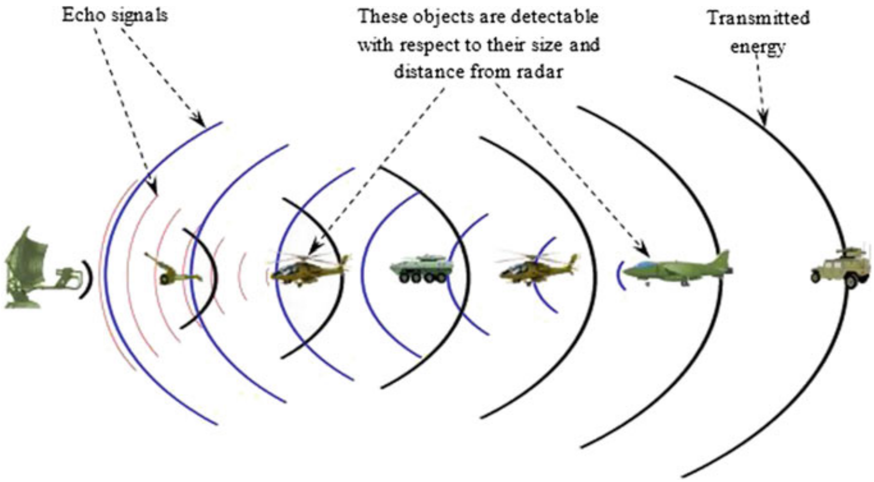


Fig. 34.2 Military objects with different sizes and distances from the radar may or may not be detected

power transmitted equal to $p(\mathbf{P}_i^t)$, antenna gain equal to $G(\mathbf{P}_i^t)$, antenna aperture equal to $A(\mathbf{P}_i^t)$, and minimal received power equal to $S_{\min}(\mathbf{P}_i^t)$. Let us also assume that there is an ideal radar (which detects any object of any size in any range in the search space) for which the peak power transmitted $p(\text{ideal})$ is maximal; the antenna gain $G(\text{ideal})$ is maximal; the antenna aperture $A(\text{ideal})$ is maximal; and the received power $S_{\min}(\text{ideal})$ is minimal. In this way, the ideal radar is the most powerful radar whose detection range $R_{\max}^t(\text{ideal})$ is maximal. Let $f_{\max}^t$ and $f_{\min}^t$ denote the worst and best function values in the population Π^t, respectively. On the basis of our assumptions, the following proportions are intuitively true.

$$p(\mathbf{P}_i^t)/p(\text{ideal}) \equiv \left((f(\mathbf{P}_i^t) - f_{\min}^t)/(f_{\max}^t - f_{\min}^t)\right), \tag{34.2}$$

$$G(\mathbf{P}_i^t)/G(\text{ideal}) \equiv \left((f(\mathbf{P}_i^t) - f_{\min}^t)/(f_{\max}^t - f_{\min}^t)\right), \tag{34.3}$$

$$A(\mathbf{P}_i^t)/A(\text{ideal}) \equiv \left((f(\mathbf{P}_i^t) - f_{\min}^t)/(f_{\max}^t - f_{\min}^t)\right), \tag{34.4}$$

$$S_{\min}(\mathbf{P}_i^t)/S_{\min}(\text{ideal}) \equiv \left(1/(f(\mathbf{P}_i^t) - f_{\min}^t)\right) / \left(1/(f_{\max}^t - f_{\min}^t)\right). \tag{34.5}$$

All ratios in both sides of Relations (34.2)–(34.4) are less than one and those coming in Relation (34.5) are greater than one. To obtain $R_{\max ij}^t$, as a portion of the maximum possible detection range $R_{\max}^t(\text{ideal})$, and from Eq. (34.1) we have:

$$\frac{K_{\text{Radar}}(\mathbf{P}_i^t)}{K_{\text{Radar}}(ideal)} = \sqrt[4]{\frac{p(\mathbf{P}_i^t)G(\mathbf{P}_i^t)A(\mathbf{P}_i^t)}{(4\pi)^2 S_{\min}(\mathbf{P}_i^t)}} \Big/ \sqrt[4]{\frac{p(\text{ideal})G(\text{ideal})A(\text{ideal})}{(4\pi)^2 S_{\min}(\text{ideal})}} \equiv \frac{f(\mathbf{P}_i^t) - f_{\min}^t}{f_{\max}^t - f_{\min}^t}. \tag{34.6}$$

By definition, σ is the size and ability of a target to reflect radar energy. To select among $\mathbf{P}_j^t, \forall j = 1, \ldots, N_B,\ j \neq i$ individuals in the population, let $\sigma(\mathbf{P}_j^t)$ be the artificial radar cross section associated to $\mathbf{P}_j^t$. On the basis of Eq. (34.1) we therefore set:

$$R_{\max ij}^t = R_{\max}^t(\text{ideal}) \times \frac{f(\mathbf{P}_i^t) - f_{\min}^t}{f_{\max}^t - f_{\min}^t} \times \sqrt[4]{\sigma(\mathbf{P}_j^t)},\ \forall j = 1, \ldots, N_B,\ j \neq i. \tag{34.7}$$

Relation (34.6) indicates that the worsen the solution $\mathbf{P}_i^t$ in terms of the function value, the higher the value of $K_{\text{Radar}}(\mathbf{P}_i^t)$should be, vice versa. It is intuitive, because as $\mathbf{P}_i^t$ becomes worsen, it should become more enable to detect possibly more individuals in the population to bias the search toward some of them with the hope of generating better solutions. On the other hand as $\mathbf{P}_i^t$ becomes good in terms of function value, it should become more restricted in detecting low quality individuals. Whenever a new solution enters to the population, the value of $f_{\max}^t$ or $f_{\min}^t$ may be updated. Intuitively we have $R_{\max}^t(\text{ideal}) = f_{\max}^t - f_{\min}^t$.

Since $\sigma(\mathbf{P}_j^t)$ is the ability of $\mathbf{P}_j^t$ to be detected by $\mathbf{P}_i^t$, it is reasonable to assume that the worsen the solution $\mathbf{P}_j^t$, in terms of the function value, the smaller the value of $\sigma(\mathbf{P}_j^t)$ should be, vice versa. That is $\sigma(\mathbf{P}_j^t) \equiv ((f_{\max}^t - f(\mathbf{P}_j^t))/(f_{\max}^t - f_{\min}^t))$. However, it seems reasonable to assume that the greater the value of $f(\mathbf{P}_j^t)$, compared to

$f(\mathbf{P}_i^t)$, the smaller chance should be given to $\mathbf{P}_j^t$ to be detected by $\mathbf{P}_i^t$. This justifies the assumption of $\sigma(\mathbf{P}_j^t) \equiv \exp(-a(f(\mathbf{P}_j^t) - f_{\min}^t)/(f(\mathbf{P}_i^t) - f_{\min}^t))$. We can therefore set $\sigma(\mathbf{P}_j^t) = ((f_{\max}^t - f(\mathbf{P}_j^t))/(f_{\max}^t - f_{\min}^t))\exp(-a(f(\mathbf{P}_j^t) - f_{\min}^t)/(f(\mathbf{P}_i^t) - f_{\min}^t))$. From Eq. (34.7) we have:

$$R_{\max ij}^t = (f(\mathbf{P}_i^t) - f_{\min}^t) \times \sqrt[4]{\left(\frac{f_{\max}^t - f(\mathbf{P}_j^t)}{f_{\max}^t - f_{\min}^t}\right) e^{-a\left(\frac{f(\mathbf{P}_j^t) - f_{\min}^t}{f(\mathbf{P}_i^t) - f_{\min}^t}\right)}},\ i \neq j. \tag{34.8}$$

Let $u(\mathbf{P}) = ((f(\mathbf{P}) - f_{\min}^t)/(f_{\max}^t - f_{\min}^t))$ be the normalized form of $f(\mathbf{P})$. We have:

$$R_{\max ij}^t = (f_{\max}^t - f_{\min}^t) \times u(\mathbf{P}_i^t) \times \sqrt[4]{(1 - u(\mathbf{P}_j^t))\exp(-au(\mathbf{P}_j^t)/u(\mathbf{P}_i^t))},\ i \neq j. \tag{34.9}$$

Definition 34.1 Let $R_{ij}^t = \left|f(\mathbf{P}_i^t) - f(\mathbf{P}_j^t)\right|$ be the distance between $\mathbf{P}_i^t$ and $\mathbf{P}_j^t$ in the function value space. We say $\mathbf{P}_j^t$ is detectable by $\mathbf{P}_i^t$ if $R_{ij}^t \leq R_{\max ij}^t$.

According to Definition 34.1, all individual solutions in Π^t (except for the ith one) whose distance with $\mathbf{P}_i^t$ in the function value space is less than $R_{\max ij}^t$, are detectable by $\mathbf{P}_i^t$. The following observations can be extracted from Eq. (34.8):

Observation 1. If $f(\mathbf{P}_i^t) = f_{\min}^t$ then $R_{\max ij}^t = 0, \forall j = 1, \ldots, N_B, i \neq j$. The best solution as an artificial radar detects nothing, since all individuals are worthless to be detected.

Observation 2. If $f(\mathbf{P}_j^t) = f_{\min}^t$ then $R_{\max ij}^t = (f(\mathbf{P}_i^t) - f_{\min}^t) = R_{ij}^t$. Any solution as an artificial radar always detects the best solution. Therefore, the best solution in the population is always detectable by any other individual in the population.

Observation 3. If $f(\mathbf{P}_j^t) = f_{\max}^t$ then $R_{\max ij}^t = 0$. The worst solution cannot be detected by any other solution. Therefore, no solution moves toward the worst solution in the population directly.

Among all detectable individuals by $\mathbf{P}_i^t$, one can be selected based on any logic as a basis for generation of a new solution in the so called Finish step of F3EA algorithm. If there was no detectable individual, one individual is selected from Π^t. The best solution found so far, if it is the result of the Fix step, also contributes in the selection. Hereafter, we assume that $\mathbf{P}_j^t$ is the selected individual.

34.3 Modeling the "Finish" Step of F3EA Algorithm

Let $\mathbf{P}_i^t$ be the ith individual in population Π^t at iteration t, which had impersonated as an artificial radar during the so called Find step. Let also $\mathbf{P}_j^t$, ($\mathbf{P}_j^t \neq \mathbf{P}_i^t$) be the corresponding selected individual. During the Finish step, the aim is to generate a new solution on the basis of $\mathbf{P}_i^t$ and with the aid of $\mathbf{P}_j^t$. For this purpose, here in this step we assume that $\mathbf{P}_i^t$ and $\mathbf{P}_j^t$, impersonate the position of a rocket launcher and a target military facility, respectively.

The conceptual model of the Finish step is simple. We assume that during the Finish step, an artificial rocket is launched from $\mathbf{P}_i^t$ towards $\mathbf{P}_j^t$ and the explosion position $\mathbf{E}_i^t$ which is determined via the projectile motion equations is treated as a new position in the search space. To develop the model of Finish step for generation of the new solutions, we need to assume that:

- The artificial rocket is a time bomb which will be exploded a certain duration after its launch.
- Neglecting the air or wind drag, the explosion time is equal to the theoretic rocket's time of flight on an inclined plane. In Physics, a projectile' usually mean an object which is in a state of free fall after it is initially thrown. We assume that immediately after projection of the rocket, the thrust stops. So through the paper we use "rocket" and "projectile" alternately.
- When the rocket is launched, it is subjected to an air drag force which acts in the opposite direction of the rocket's instantaneous direction of motion. Wind also blows which produces a force.

Now we can develop our theory to generate the new solution during the Finish step of F3EA algorithm. Let $[\mathbf{P}_i^t, u(\mathbf{P}_i^t)]_{1\times(n+1)}$ be the position of the rocket launcher in the $\mathbf{P} - u(\mathbf{P})$ coordinate system. Let $[\mathbf{P}_j^t, u(\mathbf{P}_j^t)]_{1\times(n+1)}$ be also the position of the jth artificial military object which is selected for destruction (see Fig. 34.3). From Fig. 34.3, the inclination β_{ij}^t with the horizontal is calculated as follows:

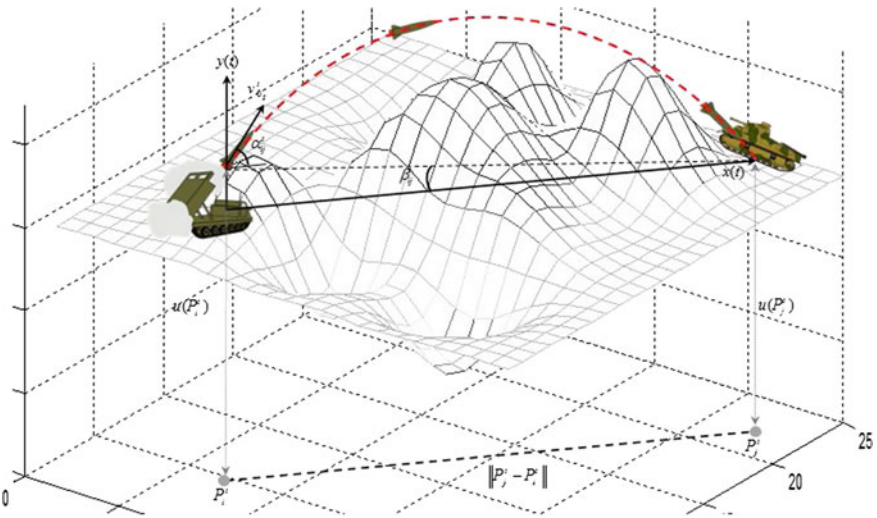


Fig. 34.3 Neglecting the air or wind drag, the rocket's trajectory of motion is parabolic and the time of flight is simply computable

$$\beta_{ij}^t = \arctan\left((u(\mathbf{P}_j^t) - u(\mathbf{P}_i^t)) \Big/ \left\|\mathbf{P}_j^t - \mathbf{P}_i^t\right\|\right). \tag{34.10}$$

Let α_{ij}^t be the angle by which the artificial rocket is launched from $\mathbf{P}_i^t$ toward $\mathbf{P}_j^t$ in the search space. For a given value of α_{ij}^t, the value of $v_{0_{ij}}^t$ (i.e., the artificial rocket initial velocity) can be obtained as [6]:

$$v_{0_{ij}}^t = \begin{cases} \sqrt{\left(AB_{ij}^t \times g \times \cos^2\beta_{ij}^t\right)/\left(2\cos\alpha_{ij}^t \times \sin(\alpha_{ij}^t - \beta_{ij}^t)\right)}, & f(\mathbf{P}_i^t) < f(\mathbf{P}_j^t) \\ \sqrt{\left(AB_{ij}^t \times g \times \cos^2\left|\beta_{ij}^t\right|\right)/\left(2\cos\alpha_{ij}^t \times \sin(\alpha_{ij}^t + \left|\beta_{ij}^t\right|)\right)}, & f(\mathbf{P}_i^t) \geq f(\mathbf{P}_j^t), \end{cases} \tag{34.11}$$

where,

$$AB_{ij}^t = \left\|[\mathbf{P}_j^t, u(\mathbf{P}_j^t)]_{1\times(n+1)} - [\mathbf{P}_i^t, u(\mathbf{P}_i^t)]_{1\times(n+1)}\right\|, \tag{34.12}$$

$$\alpha_{ij}^t = \begin{cases} \text{rand}(\beta_{ij}^t, \pi/2), & f(\mathbf{P}_i^t) < f(\mathbf{P}_j^t), \\ \text{rand}(0, \pi/2), & f(\mathbf{P}_i^t) \geq f(\mathbf{P}_j^t). \end{cases} \tag{34.13}$$

rand(a, b) is a uniformly distributed random number in the interval (a, b). Once the value of $v_{0_{ij}}^t$ was determined by Eq. (34.11) we can obtain the rocket's time of flight (T_{ij}^t) as [6]:

$$T_{ij}^t = \begin{cases} \left(2v_{0_{ij}}^t \sin\left(\alpha_{ij}^t - \beta_{ij}^t\right)\right)/g\cos\beta_{ij}^t, & f(\mathbf{P}_i^t) < f(\mathbf{P}_j^t) \\ \left(2v_{0_{ij}}^t \sin\left(\alpha_{ij}^t + \left|\beta_{ij}^t\right|\right)\right)/g\cos\left|\beta_{ij}^t\right|, & f(\mathbf{P}_i^t) \geq f(\mathbf{P}_j^t). \end{cases} \tag{34.14}$$

Now suppose that a rocket of mass m_{ij}^t is launched with velocity $v_{0_{ij}}^t$ and angle α_{ij}^t from the position $[\mathbf{P}_i^t, u(\mathbf{P}_i^t)]_{1\times(n+1)}$ toward the target position at $[\mathbf{P}_j^t, u(\mathbf{P}_j^t)]_{1\times(n+1)}$ in the $\mathbf{P} - u(\mathbf{P})$ ordinate system. Following our assumptions, we know that the rocket will be exploded at time T_{ij}^t. Under the third assumption, now the rocket is subjected to an unexpected air drag force and also the wind force. Under such circumstances, the rocket's trajectory of motion is no longer parabolic. So, it may not be able to hit the target exactly and may be exploded near the earth, somewhere close or far (depending on the wind speed and direction) from the artificial target facility (see Fig. 34.4). We can simply adopt the theory to develop the main equations of the F3EA algorithm for generation of the new solution. We need to first determine the artificial rocket mass (m_{ij}^t) launched from $\mathbf{P}_i^t$. Theories say that as the value of m gets larger, given all other parameters constant, the trajectory of projectile tends to the classic parabolic trajectory obtained under simple projectile motion. On the other hand, as the value of m gets smaller, given all other parameters constant, the projectile is more affected by the wind and air drag forces. As the result of Find step, we know that $\mathbf{P}_j^t$ is the selected target individual. So it is reasonable to bias the search direction from $\mathbf{P}_i^t$ toward $\mathbf{P}_j^t$ if $f(\mathbf{P}_j^t) < f(\mathbf{P}_i^t)$ (or alternately $u(\mathbf{P}_j^t) < u(\mathbf{P}_i^t)$) and bias the search direction away from $\mathbf{P}_j^t$, otherwise. If we set:

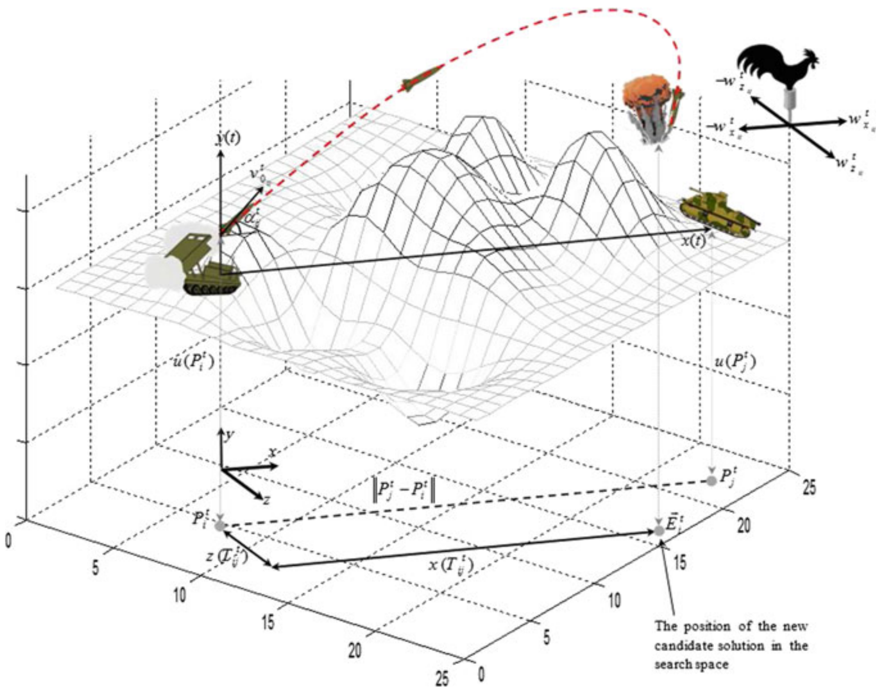


Fig. 34.4 When the artificial rocket is launched, it is subjected to air drag and wind force which cause the trajectory of motion be nonparabolic

$$m_{ij}^t = \max\left(m_{\min}, \min\left(u(\mathbf{P}_i^t)/u(\mathbf{P}_j^t), m_{\max}\right)\right) \tag{34.15}$$

we can relate determination of the search direction, as either approach to or retreat from $\mathbf{P}_j^t$, to the function values which is fit to our purpose. $m_{\min}$ and $m_{\max}$ are given constants equal to 0.01 and 100, respectively. Equation (34.15) indicates that the value of mass m_{ij}^t is determined by the ratio $u(\mathbf{P}_i^t)/u(\mathbf{P}_j^t)$. The greater (smaller) ratio dictates a greater (smaller) mass which lets the artificial rocket/projectile possibly approaches to (gets far from) $\mathbf{P}_j^t$, which is in accordance with our purpose.

Now we should simulate the wind effect. The aim is to determine the wind vector $\mathbf{w}_{ij}^t = [w_{x_{ij}}^t, 0, w_{z_{ij}}^t]_{1\times 3}$. Again, it is reasonable to relate the wind force effect to the function values. If $f(\mathbf{P}_j^t) < f(\mathbf{P}_i^t)$, it is rational that the wind force on x-axis (the axis on the line passing through $\mathbf{P}_i^t$ and $\mathbf{P}_j^t$) blows in a straight direction toward $\mathbf{P}_i^t$ to push the artificial rocket toward $\mathbf{P}_j^t$ (such a situation occurs in Fig. 34.4). Otherwise if $f(\mathbf{P}_j^t) > f(\mathbf{P}_i^t)$, it is reasonable that the wind force on x-axis blows in a direction away from $\mathbf{P}_i^t$ to push the artificial rocket back from $\mathbf{P}_j^t$. Following such a notion we set component as follows:

$$w_{x_{ij}}^t = \begin{cases} -m_{ij}^t \times v_{0_{ij}}^t \times \mathrm{rand}(0,1), & f(\mathbf{P}_i^t) < f(\mathbf{P}_j^t) \\ m_{ij}^t \times v_{0_{ij}}^t \times \mathrm{rand}(0,1), & f(\mathbf{P}_i^t) \geq f(\mathbf{P}_j^t). \end{cases} \tag{34.16}$$

From Relation (34.16) we see that the magnitude of the wind component on x-axis is proportional to the value of m_{ij}^t and $v_{0_{ij}}^t$. The greater value of m_{ij}^t, is expected to enforce the greater wind force which in turn pushes the rocket towards $\mathbf{P}_j^t$ if $f(\mathbf{P}_j^t) \leq f(\mathbf{P}_i^t)$ and outwards $\mathbf{P}_j^t$ if $f(\mathbf{P}_j^t) > f(\mathbf{P}_i^t)$.

If there is no wind component in z direction, the artificial projectile explosion position on the search space will be somewhere on the line connecting $\mathbf{P}_i^t$ and $\mathbf{P}_j^t$. However, when $w_{z_{ij}}^t \neq 0$, the projectile explosion position will deviate from the connecting line (such a situation occurs in Fig. 34.4). A suitable form for $w_{z_{ij}}^t$, would be as follows:

$$w_{z_{ij}}^t = \begin{cases} -m_{\min} \times v_{0_{ij}}^t \times \text{rand}(0,1), \text{rand}(0,1) < 0.5 \\ m_{\min} \times v_{0_{ij}}^t \times \text{rand}(0,1), \text{rand}(0,1) \geq 0.5 \end{cases} \tag{34.17}$$

The motion Eqs. (34.6) and (34.8) work in the presence of a 2-dimensional ($n = 2$) search space, truly. We therefore generalize these equations so that they work for higher (say n) dimensional search spaces, hypothetically. Let $\mathbf{E}_i^t$ be the explosion position of the artificial rocket launched from $\mathbf{P}_i^t$ toward $\mathbf{P}_j^t$, in the search space which is essentially a new solution to the problem. We are now ready to propose the equations of the Finish step to generate $\mathbf{E}_i^t$ as follows. It is worth to remind that we had assumed that the artificial rocket is a time bomb which is exploded at time T_{ij}^t (obtained by Eq. (34.14)) after it was launched.

$$x(T_{ij}^t) = w_{x_{ij}}^t T_{ij}^t + m_{ij}^t (v_{0_{ij}}^t \cos\alpha_{ij}^t - w_{x_{ij}}^t)(1 - e^{-T_{ij}^t/m_{ij}^t}), \tag{34.18}$$

$$z(T_{ij}^t) = w_{z_{ij}}^t T_{ij}^t - m_{ij}^t w_{z_{ij}}^t (1 - e^{-T_{ij}^t/m_{ij}^t}), \tag{34.19}$$

$$\mathbf{E}_i^t = \mathbf{P}_i^t + x(T_{ij}^t) \frac{(\mathbf{P}_j^t - \mathbf{P}_i^t)}{\left\|\mathbf{P}_j^t - \mathbf{P}_i^t\right\|} + z(T_{ij_k}^t) \frac{(\mathbf{Z}_{ij\perp}^t)}{\left\|\mathbf{Z}_{ij\perp}^t\right\|}. \tag{34.20}$$

In Eq. (34.18), $x(T_{ij}^t)$ is the explosion position on the so called x-axis (an axis on the line connecting $\mathbf{P}_i^t$ and $\mathbf{P}_j^t$) and in Eq. (34.19), $z(T_{ij}^t)$ is the explosion position on so called z-axis, perpendicular to the x-axis (see Fig. 34.4). To extend the theory to n-dimensional search space ($n > 2$), the x-axis can be assumed on the hyper-line connecting $\mathbf{P}_i^t$ and $\mathbf{P}_j^t$. However, the z-axis exist only imaginary. Because the reality of projectile motion subject to wind force is only in 3-dimensions. All we know about such an imaginary z-axis is that it is perpendicular to the hyper-line connecting $\mathbf{P}_i^t$ and $\mathbf{P}_j^t$. Let the z-axis be coextensive with $\mathbf{Z}_{ij\perp}^t$ which is in turn perpendicular to the hyper-line connecting $\mathbf{P}_i^t$ and $\mathbf{P}_j^t$. We therefore have $(\mathbf{P}_j^t - \mathbf{P}_i^t) \cdot \mathbf{Z}_{ij\perp}^{t'} = 0$. One solution for this equation is of form $\mathbf{Z}_{ij\perp}^t = [1, 1, \ldots, 1, 1 - \sum_{d=1}^n (p_{jd}^t - p_{id}^t)/(p_{jq}^t - p_{iq}^t), 1, \ldots, 1]_{1\times n}$. Indeed, $\mathbf{Z}_{ij\perp}^t$ is a unit vector whose qth element is equal to $1 - \sum_{d=1}^n (p_{jd}^t - p_{id}^t) \Big/ (p_{jq}^t - p_{iq}^t)$, where q is picked every time randomly from the set $\{1, 2, \ldots, n\}$.

$\mathbf{E}_i^t$ is a new solution generated in the Finish step. Once a complete solution was generated by Eq. (34.20), and before any evaluation being carried out on the quality of the solution, its feasibility is checked with respect to the range constraints and values outside of the ranges are inserted back into their range randomly.

34.4 Modeling the "Exploit" Step of F3EA Algorithm

By definition, the Exploit phase in F3EA process of targeting includes sensitive site conquering and exploitation, gathering information from the target area, and information actions to exploit the outcome of the finish phase. Inspired from the exploit phase of the real F3EA targeting methodology, the Exploit step of F3EA algorithm tries to exploit the outcome of the Finish step.

The feasible $\mathbf{E}_i^t$ solution generated by Eq. (34.20), differs from $\mathbf{P}_i^t$ in all dimensions. However on many functions, it may not be a good choice to make changes in all dimensions. Let c_i^t denotes the number of changes made in $\mathbf{P}_i^t$. To simulate the number of changes (c_i^t), we use a truncated geometric distribution [2–5].

$$c_i^t = \left\lceil \frac{\ln(1-(1-(1-q_i^t)^n)\text{rand}(0,1))}{\ln(1-q_i^t)} \right\rceil, \; c_i^t \in \{1, 2, \ldots, n\}, \tag{34.21}$$

where $q_i^t < 1, q_i^t \neq 0$. The greater positive (negative) value of q_i^t, the smaller (greater) number of changes is recommended.

Let us set $\mathbf{U}_i^t \leftarrow \mathbf{P}_i^t$. Then, c_i^t number of dimensions are selected randomly from $\mathbf{E}_i^t$ and their value are assigned to their relevant dimension in $\mathbf{U}_i^t$. We then treat $\mathbf{U}_i^t$ as the offspring output of the local Exploit step and perform the Analyze step.

34.5 Modeling the "Analyze" Step of F3EA Algorithm

The Analyze step, is a replacement step by which new solutions which are generated during the Fix or Exploit steps may enter to population or update the global best solution. In this way after performing the Exploit step, a greedy selection is carried out between $\mathbf{U}_i^t$ and $\mathbf{P}_i^t$. If $f(\mathbf{U}_i^t)$ is better than $f(\mathbf{P}_i^t)$, then we replace the ith member of Π^t with $\mathbf{U}_i^t$.

34.6 Modeling the "Fix" Step of F3EA Algorithm

The Fix step which is a local search step mimics the aiming process toward the target to monitor it in preparation for actioning. Figure 34.5 demonstrates a schematic concept of the Fix step. As can be seen from this figure, to hit the military tank target, the angle by which the rocket is launched should be acute enough that the rocket

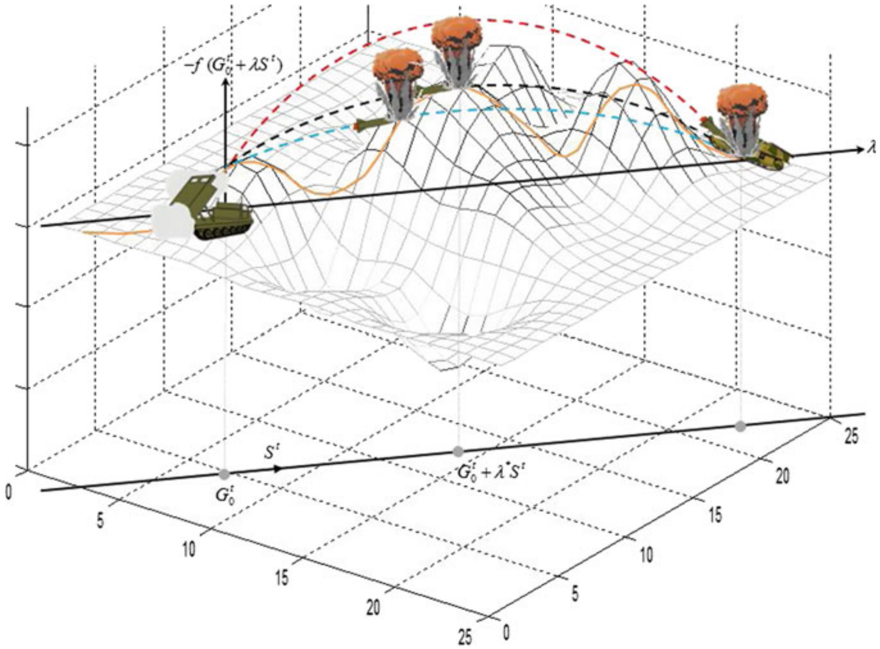


Fig. 34.5 A schematic concept of the Fix step in F3EA algorithm

traverses the highest peak. Any successful trajectory must pass over the highest peak. We implement such an idea as a single-variable optimization problem in the Fix step of F3EA algorithm to obtain locally improved solutions. In this way, the Fix step of F3EA algorithm can be thought as a local search phase, in general.

Mathematically speaking, let $\mathbf{G}_0^t$ be an individual representing the position of an artificial rocket launcher in the search space and let $\mathbf{S}^t$ be a search direction. According to the above discussion, the Fix step in F3EA algorithm includes searching for the position of the deepest valley (note that we are seeking the minimum of the scalar function) on the line passing through $\mathbf{G}_0^t$, and in parallel with $\mathbf{S}^t$, which can be expressed as a one-dimensional optimization problem as follows:

$$\min\ f(\mathbf{G}_0^t + \lambda \mathbf{S}^t)$$
$$\text{s.t.} \begin{cases} \lambda_{\min} \le \lambda \le \lambda_{\max} \\ \lambda_{\min} = \max\limits_{d=1,\dots,n} \left\{ \left((x_{\min,d} - g_{0d}^t)/s_d^t \right) \Big|_{s_d^t > 0}, \left((x_{\max,d} - g_{0d}^t)/s_d^t \right) \Big|_{s_d^t < 0} \right\} \\ \lambda_{\max} = \min\limits_{d=1,\dots,n} \left\{ \left((x_{\max,d} - g_{0d}^t)/s_d^t \right) \Big|_{s_d^t > 0}, \left((x_{\min,d} - g_{0d}^t)/s_d^t \right) \Big|_{s_d^t < 0} \right\}, \end{cases} \tag{34.22}$$

where, $\lambda_{\min}$ and $\lambda_{\max}$ are obtained based on the fact that $\mathbf{X}_{\min} \le \mathbf{G}_0^t + \lambda \mathbf{S}^t \le \mathbf{X}_{\max}$. Components s_d^t, $\forall d = 1, \dots, d$ are obtained successively from the following one-dimensional optimization problems, where $\mathbf{G}_d^t = \mathbf{G}_{d-1}^t + s_d^t \mathbf{e}_d$.

$$\min \; f(\mathbf{G}_{d-1}^{t} + s_d^t \mathbf{e}_d) \tag{34.23}$$

$$\text{s.t. } \gamma_d^t (x_{\min,d} - g_{d-1,d}^t) \le s_d^t \le \gamma_d^t (x_{\max,d} - g_{d-1,d}^t), \tag{34.24}$$

where γ_d^t is every time set randomly as 0.05 to shrink the line search extent for local exploration or 1.00 for global exploration. $\mathbf{e}_d$ is the dth coordinate unit vector.

Let λ^* be the optimal solution of an instance of problem (34.22), then $\mathbf{G}_0^t + \lambda^* \mathbf{S}$ is the position of the new solution generated at the end of the Fix step. To improve the local search ability of F3EA algorithm and to steer possibly the search toward fruitful areas of the search space, we always set $\mathbf{G}_0^t \leftarrow \mathbf{G}_{\text{best}}^t$. Given $\mathbf{G}_{\text{best}}^t$ as its input, the Fix step may be executed once a new generation is started.

To search for λ^* via *fminbnd* function in Matlab, the number of function evaluations is always set equal to 10.

34.7 Computational Experiments

In order to test the capability of F3EA algorithm for global optimization, a set of 5 benchmark functions are selected. These functions are summarized in Table 34.1. For all functions, the number of variables is considered as 30 ($n = 30$). All functions are optimized in the absence of any constraints, with the exception of the variable ranges constraints. The termination criteria is either counting 1E+05 function evaluations or reaching the global minimum within the gap of 1E−3. The performance of F3EA algorithm is compared with different evolutionary and swarm intelligence algorithms like ABC and TLBO. The results of these algorithms have been directly reported from Kashan [4]. Results obtained by F3EA algorithm are compared with the results of other rivals in terms of the mean and standard deviation (SD) of the number of evaluations before termination and the percent of successful runs (SR) among 50 replications (see Table 34.2).

Table 34.1 Test functions

Sphere	$f_1(\mathbf{x}) = \sum_{i=1}^{n} x_i^2$	$x_i \in [-100, 100]$
Rosenbrock	$f_2(\mathbf{x}) = \sum_{i=1}^{n-1} 100(x_i^2 - x_{i+1})^2 + (1 - x_i)^2$	$x_i \in [-30, 30]$
Rastrigin	$f_3(\mathbf{x}) = \sum_{i=1}^{n} (x_i^2 - 10\cos(2\pi x_i) + 10)$	$x_i \in [-5.12, 5.12]$
Ackley	$f_4(\mathbf{x}) = -20\exp\left(-0.2\sqrt{1/n \cdot \sum_{i=1}^{n} x_i^2}\right) - \exp(1/n \cdot \sum_{i=1}^{n} \cos(2\pi x_i)) + 20 + e$	$x_i \in [-32, 32]$
Schwefel	$f_5(\mathbf{x}) = -\sum_{i=1}^{n} \left(x_i \sin(\sqrt{\lvert x_i \rvert})\right)$	$x_i \in [-500, 500]$

Table 34.2 Results obtained by different algorithms

Function	ABC			TLBO			F3EA		
	Mean	SD	SR	Mean	SD	SR	Mean	SD	SR
Sphere	9264	1481	100	4648	148	100	691	404	100
Rosenbrock	100000	0	0	100000	0	0	97332	6516	20
	(0.936)	(1.76)		(16.321)	(1.356)		(0.78)	(1.534)	
Rastrigin	26731	9311	100	34317	13866	100	639	431	100
Ackley	16616	1201	100	3868	2634	100	1139	773	100
Schwefel	64632	23897	86	100000	0	40	59260	4051	100

The size of the population, is set equal to 50 for F3EA algorithm. Results of mean performances show that F3EA achieves the global minimum of 4 out of 5 problems faster than ABC and TLBO. On sphere function, all of ABC, TLBO and F3EA algorithms are able to find the global optimum in all runs. However, the convergence speed of F3EA is significantly higher compared to ABC and TLBO algorithms. On the Rosenbrock function, none of ABC and TLBO are able to find the global minimum in any run. However, F3EA is able to find the true minimum several times. On this function, the mean performance of F3EA is also better than both of ABC and TLBO. Values in parenthesis denote the mean and standard deviation among the best function values found in 50 runs. The ABC's performance is also remarkable but TLBO shows a poor mean performance. On Rastrigin and Ackly functions all algorithms are successful in all runs. Again F3EA converges very faster than others. Finally on Schwefel function, while F3EA is always able to find the global minimum, ABC and TLBO fail to do this. However they are able to find the global minimum generally. Again ABC performs better than TLBO.

34.8 Conclusion

The F3EA algorithm was introduced formally as a new algorithm for optimization. It is composed of Find-Fix-Finish-Exploit-Analyse (F3EA) steps which mimics the targeting process in contemporary warfare. The function surface is treated as an artificial battle field by the F3EA algorithm in which any individual in the population determines the position of an artificial military object or installations to be selected, attacked and destroyed in the artificial warfare. The mathematical models of different steps of F3EA metaheuristic was developed where we used the underlying theories of Physics of radar and projectile motion. From the experiments on finding the global optimum of benchmark functions, it was revealed that the new algorithm is a dependable tool and converges very fast to the global minimum. For future research, there would be a great interest on testing the performance of the new algorithm on constraint optimization problems and real word engineering problems.

Acknowledgments This work is partly supported by the Grant-in-Aid for Scientific Research (C) of Japan Society of Promotion of Science (JSPS): No. 15K00357.

References

1. Ferry M (2013) F3EA–a targeting paradigm for contemporary warfare. Aust Army J X(1):49–64
2. Husseinzadeh Kashan A (2011) An efficient algorithm for constrained global optimization and application to mechanical engineering design: league championship algorithm (LCA). Comput-Aided Des 43(12):1769–1792
3. Husseinzadeh Kashan A (2014) League championship algorithm (LCA): an algorithm for global optimization inspired by sport championships. Appl Soft Comput 16:171–200

4. Husseinzadeh Kashan A (2015a) An effective algorithm for constrained optimization based on optics inspired optimization (OIO). Comput-Aided Des 63:52–71
5. Husseinzadeh Kashan A, Karimi B (2010) A new algorithm for constrained optimization inspired by the sport league championships. In: 2010 IEEE Congress on evolutionary computation (CEC), IEEE, pp 1–8
6. Mestre ND (1990) The mathematics of projectiles in sport, vol 6. Cambridge University Press, Cambridge
7. Norton KA, Omberg AC (1947) The maximum range of a radar set. Proc IRE 35(1):4–24

Chapter 35
Bi-Objective Integer Programming of Hospitals Under Dynamic Electricity Price

Shabnam Mahmoudzadeh Vaziri, Babak Rezaee and Masoud Amel Monirian

Abstract In response to rising costs of health services and competitive environment, health care organizations have to provide high quality services at lowest possible costs. On the other hand, energy prices are increasing due to the depletion of fossil fuel sources which cause an increment in health centers costs. Given these considerations, it is essential to find ways to use energy more efficiently. This paper presents a novel model for energy management in hospitals as a non-isolated micro grid that is connected to the main grid by the distribution transmission lines. Minimizing the energy costs (considering revenue, renewable energy subsidies and overtime costs) and minimizing the displeasure of surgeons and patients will be the target. We develop bi-objective integer linear programming model for this problem. It's assumed that the hospital can buy its power shortage from the main grid and is also able to sell the extra energy produced to the electricity market. It is also considered that the cost of purchasing energy from the grid is determined based on the hourly market prices of electricity.

Keywords Health centers · Energy use · Bi-objective integer linear programming

35.1 Introduction

Healthcare forms financial concern for governments all over the world. Due to developing technologies we are able to decrease health care costs and expenditures [19]. Most of the expenditures of health cares, approximately 31 %, refer to hospitals [7]. From patients' point of view hospitals are expensive as well so they are forced to decrease costs. Based on last surveys for a family with four members, 48 % of their healthcare expenses belong to hospitals [15]. In literature, operation rooms attract special attention as they involve largest costs and also bring largest rev-

S.M. Vaziri (✉) · B. Rezaee · M.A. Monirian
Faculty of Engineering, Industrial Engineering Department,
Ferdowsi University of Mashhad, Mashhad, Iran
e-mail: shabnam_vaziri@yahoo.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_35

enues [1, 3]. In most works, authors consider two types of patients, elective and nonelective patients. Elective patients are whom that their surgery can be scheduled a day ahead but nonelective patients pertain to unexpected surgeries so they need to be scheduled in short time. We call a nonelective surgery as an emergency if it has to do as soon as possible or an urgency if it can be delayed for a short time [9]. We can optimize health care problems from different perspectives, for example hospital administrator wants to reach high service level by low costs but medical staff could aim to minimize the overtime work rather than low costs, and patients desire high quality with minimum waiting time [4, 10]. Medical system is evolving every day and the number of patients is growing due to population aging and emergence of new disease [13]. Hospitals and especially public hospitals don't have enough budget so they seek for ways to reduce their costs and increase their efficiency [14]. Also the number of health cares is increasing and they evolved as a business industry because their competition increases [6]. Energy use confront an increment in recent years and predicted to have growth of 56 % from 2010 to 2040. As a result of environmental issues and deficiency of fossil fuel resources, the energy price is increasing [17]. If hospitals and health centers use energy in an efficient way, they shorten their consumption and as a result they pay less bills and reduce their costs. Another way to reduce energy costs is implementing alternative ways for generating energy [16]. Renewable energy resources, especially wind and solar resources, are appropriate alternatives for fossil fuel sources [2]. Some programs are established to use energy more efficiently such as demand response and demand dispatch [5, 18]. Demand response is a program created to persuade end customers to change their electric use in order to reduce peak demands [11]. Demand dispatch aims at changing the consumption profile in order to follow the production rate with controlling dispatchable loads [12].

Angelis et al. [8] proposed a mathematical model for residential consumers in order to reduce costs. They considered that renewable resources can produce some of their need and some part of produced energy sold out to the grid. The model determined the start time of each schedulable appliances in order to minimize the costs.

Zhao et al. [20] considered two categories of appliances, automatically operated appliances like washing machine and manual operated appliances such as television and computer. The presented model minimized the costs and also minimized the delay time rate as customers hope that their appliances start work as soon as possible.

Farimani and Mashhadi [12] used demand dispatch concept. They categorized loads into two groups, dispatchable loads and non patchable loads. The proposed model use dispatchable loads and adjust appliance start time in order to follow the generation and also minimize the costs.

With a view to manage energy use in health centers and hospitals, in this paper we consider elective patients and other dispatchable loads in hospitals such as laundry department and labs to schedule their times in order to follow energy generation and reduce costs. We assume that energy in hospitals can supply by wind and solar renewable energy resources or grid. Patients expect that all their works start with minimum waiting time and also surgeons prefer to have surgeries in an especial working time. In this paper, we minimize displeasure of surgeons and patients too.

35.2 Problem Description

Energy price increases due to depletion of fossil fuel sources and it causes increment in health centers costs. To overcome the competition among health centers, hospitals can use energy programs to reduce their consumption. In this paper, we consider a hospital as a micro grid and it is able to produce part of its energy by renewable energy resources like wind turbines and solar panels. As renewable resources are dependent on natural situations, they are not able to meet the demand in all time intervals. So, it is assumed that the micro grid, hospital, is connected to macro grid through distribution transmission lines and the shortage compensated by macro grid. The hospital is also able to sell the extra energy production to the electricity market. The electricity price from the grid varies as a time based profile, which is given 24 h in advance. Also government motivates renewable resources by paying subsidy to micro grids. In this research, we consider elective patients, laundry departments and labs as activities which their start time must be determined in order to minimize the costs. Each surgeon has a proper working period and if we arrange a surgery out of the period we should pay extra money to surgeon and also it causes displeasure. Similarly each task (surgeries and experiments) has specific period that should be done in that interval but patients want to receive their tasks as soon as possible and as we get far from the start time of slot, their displeasure increases. To implement the model, a day is divided to 96 time intervals (each time interval is 15 min).

To model the problem, the following notations are defined:

Indices

i: Number of surgeries, $i = 1, \dots, I$;
j: Number of experiments, $j = 1, \dots, J$;
z: Number of laundry tasks, $z = 1, \dots, Z$;
t: Number of time intervals, $t = 1, \dots, T$.

Parameters

p_i: Energy consumption of surgery i;
q_j: Energy consumption of experiment j;
k_z: Energy consumption of laundry z;
c_t: Energy price that bought from macro grid at time interval t (kWh);
e: Renewable energy subsidy (kWh);
f: The price of selling power to grid (kWh);
$[a, b]$: Proper start and end time interval of surgeons;
$[g, h]$: Start and finish time interval of surgery i;
$[g', h']$: Start and finish time interval of experiment j;
$[g'', h'']$: Start and finish time interval of laundry z;
l_i: Duration of surgery i;

l'_j: Duration of experiment j;
l''_z: Duration of laundry z;
OR: Number of operation rooms;
R_t: Upper limit of total renewable resources at time t (Kw);
o: Overtime cost
M: A large number.

In this paper we assumed that the renewable energy resources have already been installed and the marginal cost of renewable energy neglected and omitted from the objective function.

Decision variables

The next six variables show the start and finish time of surgeries, experiments and laundries.

$$TS_{i,t} = \begin{cases} 1, & \text{if surgery } i \text{ starts at time } t, \\ 0, & \text{otherwise,} \end{cases}$$

$$TS'_{j,t} = \begin{cases} 1, & \text{if experiment } j \text{ starts at time } t, \\ 0, & \text{otherwise,} \end{cases}$$

$$TS''_{z,t} = \begin{cases} 1, & \text{if laundry } z \text{ starts at time } t, \\ 0, & \text{otherwise,} \end{cases}$$

$$TE_{i,t} = \begin{cases} 1, & \text{if surgery } i \text{ finishes at time } t, \\ 0, & \text{otherwise,} \end{cases}$$

$$TE'_{j,t} = \begin{cases} 1, & \text{if experiment } j \text{ finishes at time } t, \\ 0, & \text{otherwise,} \end{cases}$$

$$TE''_{z,t} = \begin{cases} 1, & \text{if laundry } z \text{ finishes at time } t, \\ 0, & \text{otherwise.} \end{cases}$$

$w_{i,t}$: the status of surgery i at time t (on $=1$, off $=0$);
$w'_{j,t}$: the status of experiment j at time t (on $=1$, off $=0$);
$w''_{z,t}$: the status of laundry z at time t (on $=1$, off $=0$);
r_t: power sent to hospital from renewable resources at time t (Kw);
s_t: renewable energy sold to grid (Kw);

Rest of variables are defined in order to linearize the mathematical model.

$y_{i,t}$: binary variable ($1 =$ if the task is not done in surgeon's proper time);
$u_{i,t}$: Auxiliary variable;
$x_{i,t}$: Auxiliary variable;
$v_{i,t}$: Auxiliary variable;

We propose a bi-objective mathematical model for the aforementioned problem in the coming 24 h as follows. The first objective function is minimizing energy cost in hospitals.

$$\min \sum_{t=1}^{T}\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{z=1}^{Z}\left[(p_i w_{i,t} + q_j w'_{j,t} + k_z w''_{z,t}) - r_t\right] c_t - \sum_{t=1}^{T}(er_t + fs_t) \quad (35.1)$$

$$+ \sum_{t=1}^{T}\sum_{i=1}^{I}\left[tTE_{i,t} - \max\left\{bTS_{i,t-l_i}, (t-l_i)TS_{i,t-l_i}\right\}\right] y_{i,t} o.$$

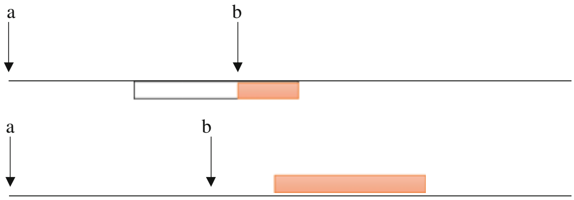


Fig. 35.1 Surgeon's displeasure cost

The first expression determines the amount of energy that should buy from grid. The second term shows the amount of incentives receive from government for using renewables and amount of energy sell to macro grid. The last expression shows the overtime displeasure (overtime) cost of surgeons and it depends on the distance from b. Figure 35.1 shows this problem. The second objective minimizes displeasure.

$$\min \sum_{t=1}^{T}\sum_{i=1}^{I}\frac{(t-g_i)TS_{i,t}}{h_i-l_i-g_i}+\sum_{t=1}^{T}\sum_{j=1}^{J}\frac{(t-g'_j)TS'_{j,t}}{h'_j-l'_j-g'_j}+\sum_{t=1}^{T}\sum_{i=1}^{I}(t-b)TE_{i,t}y_{i,t}. \tag{35.2}$$

The first two terms represent displeasure of patients. They prefer to receive their service as soon as possible and as we get far from the beginning of the task interval, their displeasure increases. The last term states the surgeon's displeasure as the surgery starts after their working period.

The constraints are defined as follows,

$$\sum\nolimits_{t\geq g_i}^{h_i-l_i} TS_{i,t}=1,\quad \sum\nolimits_{t\geq g_i+l_i}^{h_i} TE_{i,t}=1,\quad \forall i, \tag{35.3}$$

$$\sum\nolimits_{t\geq g'_j}^{h'_j-l'_j} TS'_{j,t}=1,\quad \sum\nolimits_{t\geq g'_j+l'_j}^{h'_j} TE'_{j,t}=1,\quad \forall j, \tag{35.4}$$

$$\sum\nolimits_{t\geq g''_z}^{h''_z-l''_z} TS''_{z,t}=1,\quad \sum\nolimits_{t\geq g''_z+l''_z}^{h''_z} TE''_{z,t}=1,\quad \forall z, \tag{35.5}$$

$$TS_{i,t}=TE_{i,t+l_i},\quad \forall i, g_i\leq t\leq h_i-l_i, \tag{35.6}$$

$$TS'_{j,t}=TE'_{j,t+l'_j},\quad \forall j, g'_j\leq t\leq h'_j-l'_j, \tag{35.7}$$

$$TS''_{z,t}=TE''_{z,t+l''_z},\quad \forall z, g''_z\leq t\leq h''_z-l''_z, \tag{35.8}$$

$$w_{i,t}=w_{i,t-1}+TS_{i,t}-TE_{i,t},\quad \forall i,t, \tag{35.9}$$

$$w'_{j,t}=w'_{j,t-1}+TS'_{j,t}-TE'_{j,t},\quad \forall j,t, \tag{35.10}$$

$$w''_{z,t}=w''_{z,t-1}+TS''_{z,t}-TE''_{z,t},\quad \forall z,t, \tag{35.11}$$

$$\sum\nolimits_{i} w_{i,t}\leq OR,\quad \forall t, \tag{35.12}$$

$$r_t+s_t\leq R_t,\quad \forall t, \tag{35.13}$$

$$(t-b)TE_{i,t}\leq My_{i,t},\quad \forall i,t. \tag{35.14}$$

First objective function (35.1) and (35.2) are nonlinear. To make them linear, constraints (35.15)–(35.20) are joined to model and the objective functions are changed as (35.21) and (35.22).

$$u_{i,t} \geq bTS_{i,t-l_i}, \quad \forall i, t, \tag{35.15}$$

$$u_{i,t} \geq (t - l_i)TS_{i,t-l_i}, \quad \forall i, t, \tag{35.16}$$

$$TE_{i,t} + y_{i,t} - 1 \leq x_{i,t}, \quad \forall i, t, \tag{35.17}$$

$$\frac{1}{2}(TE_{i,t} + y_{i,t}) \geq x_{i,t}, \quad \forall i, t, \tag{35.18}$$

$$u_{i,t} - M(1 - y_{i,t}) \leq v_{i,t} \leq u_{i,t} + M(1 - y_{i,t}), \quad \forall i, t, \tag{35.19}$$

$$v_{i,t} \leq My_{i,t}, \quad \forall i, t. \tag{35.20}$$

$$\begin{aligned} \min \ & \sum\nolimits_{t=1}^{T} \sum\nolimits_{i=1}^{I} \sum_{j=1}^{J} \sum\nolimits_{z=1}^{Z} \left[(p_i w_{i,t} + q_j w'_{j,t} + k_z w''_{z,t}) - r_t \right] c_t - \sum\nolimits_{t=1}^{T} (er_t + fs_t) \\ & + \sum\nolimits_{t=1}^{T} \sum\nolimits_{i=1}^{I} otx_{i,t} - \sum\nolimits_{t=1}^{T} \sum\nolimits_{i=1}^{I} ov_{i,t} \end{aligned} \tag{35.21}$$

$$\begin{aligned} \min \ & \sum\nolimits_{t=1}^{T} \sum\nolimits_{i=1}^{I} \frac{(t - g_i)TS_{i,t}}{h_i - l_i - g_i} + \sum\nolimits_{t=1}^{T} \sum\nolimits_{j=1}^{J} \frac{(t - g'_j)TS'_{j,t}}{h'_j - l'_j - g'_j} \\ & + \sum\nolimits_{t=1}^{T} \sum\nolimits_{i=1}^{I} (t - b)x_{i,t}. \end{aligned} \tag{35.22}$$

Constraints (35.3)–(35.5) represent start and finish time of each task. Constraints (35.6)–(35.8) assure that tasks be done continuously. Constraints (35.9)–(35.11) show the on or off situation of tasks in each time interval. Operation rooms are limited and (35.13) shows this constraint. Constraint (35.12) states that renewables exported to grid and used for tasks should equal to or less than the renewable generation.

35.3 Experimental Result

We implement the model with real world data from a hospital in Iran. In order to solve model with CPLEX software we used weighted sum method. Hospital has ten operation rooms and overtime cost is 30. Wind power, solar power and energy price are shown in Figs. 35.2, 35.3 and 35.4, respectively. According to limited pages we just present some data in Table 35.1.

The experimental results, start time of activities, is presented in Fig. 35.5. After implementing model in hospital the costs reduced 10 % and displeasure reduced 3 %.

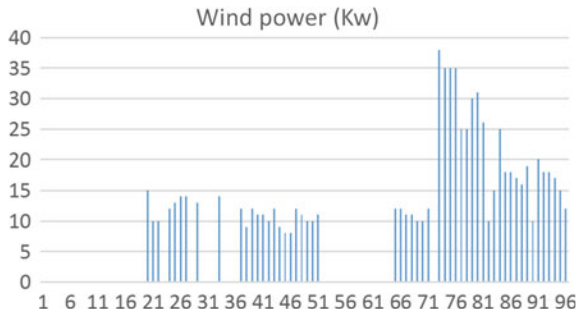


Fig. 35.2 Wind generation over time

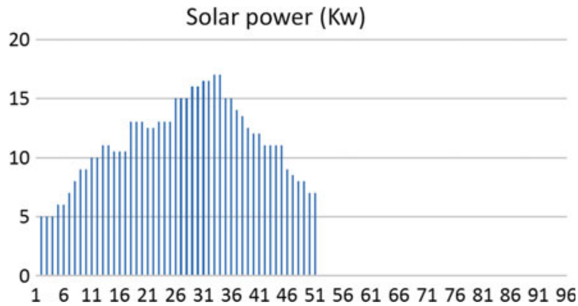


Fig. 35.3 Solar generation over time

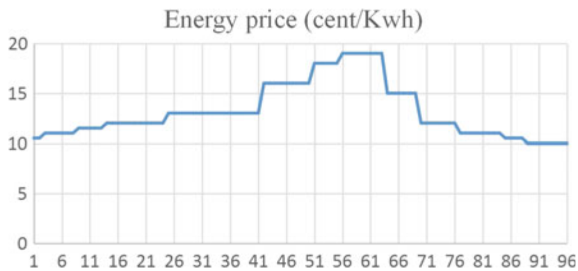


Fig. 35.4 Energy price over time

Table 35.1 Data

Tasks	Start time slot	Finish time slot	Number of time intervals (L)	Interval energy (Kw)
Surgery 1	25	41	10	1
Surgery 2	9	25	7	0.5
Surgery 3	14	29	8	0.6
Surgery 4	20	33	5	0.5
Surgery 5	10	40	15	0.5
Surgery 6	21	37	4	0.8
Surgery 30	20	40	15	0.9
Experiment 1	49	95	25	0.6
Experiment 2	33	49	10	0.8
Experiment 3	50	95	30	2
Experiment 4	25	49	8	1.5
Experiment 5	33	49	5	0.6
Laundry 1	73	95	6	0.8
Laundry 2	53	95	10	1
Laundry 3	57	95	8	0.6

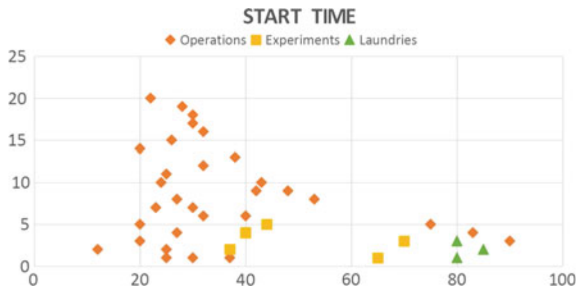


Fig. 35.5 Experimental results

35.4 Conclusion

According to increment in the number of health centers and their competition for attracting patients, it is essential to use energy efficiently. In this paper, we presented a bi-objective model to schedule tasks in hospitals in order to reduce costs and minimize displeasure of patients and surgeons. We assumed hospitals as a non-isolated micro grid that is able to sell energy to macro grid or buy energy from grid. The model solved with real world data for a hospital in Iran.

We considered deterministic parameters but in reality most parameters are uncertain like surgery time, so for future works authors can consider uncertain parameters in model. Other constraints according to conditions in hospitals can be examined by authors and they can present sensitivity analysis and compare different scenarios that can happen.

Acknowledgments The authors would like to acknowledge Professor Mitsuo Gen for his scientific support.

References

1. Aringhieri R, Landa P et al (2015) A two level metaheuristic for the operating room scheduling and assignment problem. Comput Oper Res 54:21–34
2. Aryanpur V, Shafiei E (2015) Optimal deployment of renewable electricity technologies in Iran and implications for emissions reductions. Energy 91:882–893
3. Association HFM et al (2003) Achieving operating room efficiency through process integration. Healthc Financ Manag: J Healthc Financ Manag Assoc 57(3):suppl–1
4. Batun S, Denton BT et al (2011) Operating room pooling and parallel surgery processing under uncertainty. INFORMS J Comput 23(2):220–237
5. Brooks A, Lu E et al (2010) Demand dispatch. IEEE Power Energy Mag 8(3):20–29
6. Cardoen B, Demeulemeester E, Beliën J (2009) Optimizing a multiple objective surgical case sequencing problem. Int J Prod Econ 119(2):354–366
7. Centers for Medicare and Medicaid Services (2010) Office of the actuary. National health statistics group, national health care expenditures data
8. De Angelis F, Boaro M et al (2013) Optimal home energy management under dynamic electrical and thermal constraints. IEEE Trans Ind Inf 9(3):1518–1527
9. Demeulemeester E, Beliën J et al (2013) Operating room planning and scheduling. Handbook of healthcare operations management. Springer, Berlin, pp 121–152
10. Denton BT, Rahman AS et al (2006) Simulation of a multiple operating room surgical suite. In: Proceedings of the 38th conference on Winter simulation, Winter simulation conference, pp 414–424
11. DoE U (2006) Benefits of demand response in electricity markets and recommendations for achieving them. US department energy, Washington, technical report
12. Farimani FD, Mashhadi HR (2015) Modeling and implementation of demand dispatch approach in a smart micro-grid. Integral methods in science and engineering. Springer, Berlin, pp 129–141
13. Fei H, Meskens N, Chu C (2010) A planning and scheduling problem for an operating theatre using an open scheduling strategy. Comput Ind Eng 58(2):221–230
14. Liu Y, Chu C, Wang K (2011) A new heuristic algorithm for the operating room scheduling problem. Comput Ind Eng 61(3):865–871
15. Mayne L, Girod C, Weltz S (2011) Milliman medical index. Milliman, Seattle
16. Tasri A, Susilawati A (2014) Selection among renewable energy alternatives based on a fuzzy analytic hierarchy process in indonesia. Sustain Energy Technol Assess 7:34–44
17. US Energy Information Administration (2014) Annual energy outlook
18. Vardakas JS, Zorba N, Verikoukis CV (2015) A survey on demand response programs in smart grids: pricing methods and optimization algorithms. IEEE Commun Surv Tutor 17(1):152–178
19. Wang YC, McPherson K et al (2011) Health and economic burden of the projected obesity trends in the usa and the UK. Lancet 378(9793):815–825
20. Zhao Z, Lee WC et al (2013) An optimal power scheduling method for demand response in home energy management system. IEEE Trans Smart Grid 4(3):1391–1400

Part III
Information Technology

Chapter 36
Longitudinal Joint Model for Instrument and Person Memories in a Quality of Life Study

Mounir Mesbah

Abstract Specific longitudinal methods allowing for the analysis of latent variables have not yet been much developed despite the growing use of self-reported questionnaires in clinical trials aimed at measuring and evaluating many different latent variables such as QoL in cancer trials, dementia in Alzheimer trials, etc. The benefit of combining longitudinal analysis and IRT modelling using Rasch models for binary items has already been studied in the context of clinical trials and seems very promising. In this work, we will present a new longitudinal model where the memory of the instrument and the memory of the person are taken into account jointly. We present the model, its graphical properties in the context of a real longitudinal Health Related Quality of Life study. Finally, we discuss alternative strategies to deal with the same problem.

Keywords Measurement models · Rasch family models · Latent variable models · Instrument memory · Longitudinal · Complex model

36.1 Introduction

We consider the context of a longitudinal study, where participants are interviewed about their quality of life, at regular dates of visit, previously established. The interviews consist to fulfill a questionnaire in which patients are asked multiple choice questions, chosen in order to measure, at the time of the visit, the latent (unobserved) trait (quality of life). We focus here on one unidimensional latent trait. We suppose that the unique effect of time on the observations (evolution) occurs through latent components. So, we assume that measurement properties of the instrument (questionnaire) are not changing.

The Short-Form twelve (SF-12) is a shortened version (twelve items) of the Medical Outcomes Study 36-items Short-Form Health Survey (SF-36) a generic well

M. Mesbah (✉)
University'e Pierre et Marie Curie, Paris, France
e-mail: mounir.mesbah@upmc.fr

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_36

Table 36.1 The questionnaire

Questions	Label	Contents
WHB	Wq1	How much do you enjoy your life?
WHB	Wq2	How satisfied are you with your ability to learn new information?
WHB	Wq4	How much do you value yourself?
WHB	Wq5	How often do you have negative feelings, such a blue mood, despair, anxiety, depression?
SF12	sf4	Does your health now limit you in moderate activities such as moving a table, pushing a vacuum cleaner, . . .
SF12	sf6	During the past four weeks, have you accomplished less than you would like?
SF12	sf7	During the past four weeks, were you limited in the kind of work or other regular activities you do?
SF12	sf9	During the past four weeks, did you not do work or other regular activities as carefully as usual?
SF12	sf10	How much time during the past 4 weeks have you felt calm and peaceful?
SF12	sf11	How much of the time during the past 4 weeks did you have a lot of energy?
SF12	sf12	How much time during the past 4 weeks have you felt down?

known questionnaire and the WHOQOL HIV Brief (WHB), is a shortened version of the WHOQOL HIV, an HIV (Human Immunodeficiency Virus) specific questionnaire developed by the WHO (World Health Organisation). From the WHB, we focus on the psychological sub-dimension (five items). Mesbah [9], starting with those seventeen items, and using the Backward Reliability Curve (BRC) method to find among the 12 questions SF12 and 5 Questions WHB, a unidimensional subset of questions. The text of these 11 unidimensional questions is presented in Table 36.1.

36.2 Choice of the Components of the Joint Model

Specification of a latent variable model is usually done by the choice of two components:

- The measurement model: a measurement model is a conditional probability model linking the observed variables to the latent variables,
- The probability distribution for the latent variables.

In our setting,

- At a fixed time, the latent variable is a scalar.
- At a fixed time, the joint distribution of the observed items and the unobserved latent variable is described by its independence graph in Fig. 36.1 or 36.2: two items are independent conditional to the latent.
- We assume that the instrument parameters, i.e., the parameters of the measurement model, are not changing over time.

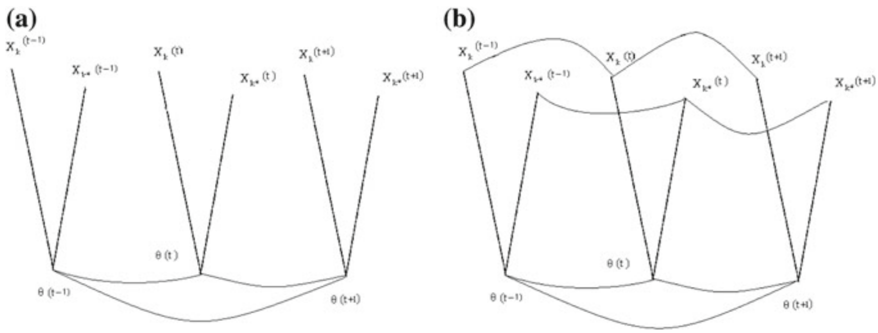


Fig. 36.1 Rasch process without (**a**) or with (**b**) instrument memory but with person memory. **a** Model without instrument memory. **b** Model with instrument memory

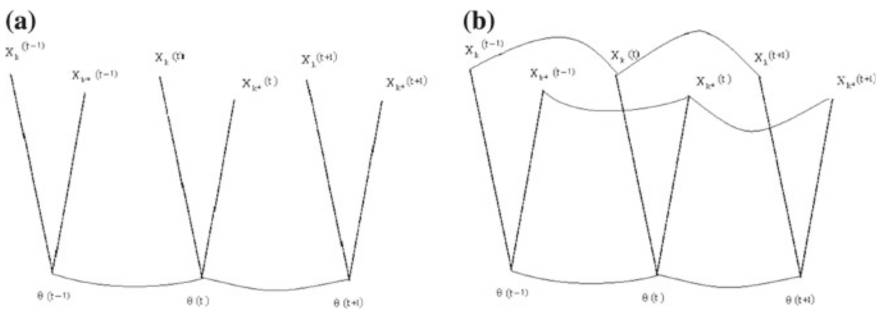


Fig. 36.2 Rasch process without (**a**) or with (**b**) instrument memory but without person memory. **a** Model without instrument nor person memory. **b** Model with instrument and without person memory

The longitudinal aspect of our family of models is completely described by the independence graph of Fig. 36.1, the choice of the measurement model and the joint distribution of the latent process $(\Theta(1), \ldots, \Theta(T))$.

In Fig. 36.2 is presented a graphical interpretation of the model with two items and three time points. For simplicity, in this graphical representation, we focus only on time $t-1$, t and $t+1$. The whole graph can be easily obtained with similar rules. The interpretation is in term of conditional independence. A missing edge between two variables means that these two variables are independent conditionally to the remaining.

An important remark is, that, even if we assume Instrument memory dependence, we do not relax the invariance property of the instrument which is the strongest Rasch property. In our model, the item parameters β_k are still invariant. They are constant over time.

36.2.1 Choice of the Measurement Model

A large number of measurement models are possible. Item response theory is the field of psychometry devoted to that purpose. When the responses are ordinal, two reasonable choices could be the partial credit model or the graded response model.

- Both are unidimensional models from the Rasch family of measurement models.
- Both own the nice property of independence of observed variables conditional to the latent (Fig. 36.2).
- Both are logistic model.
- The raw score (sum of item responses) of an individual is a sufficient statistic for the latent parameter under the Partial Credit Model.
- The raw score of an individual is not a sufficient statistic for the latent parameter under the Graded Response Model.

Let $X_j = x$ with $x = 0, \ldots, m$, the modalities of item j, and β_{jx} the parameter of modality x of item j.

- The Partial Credit Model (PCM [7]) is defined as:

$$\pi_{jx\theta} = \mathrm{Prob}(X_j = x \mid \theta) = \frac{\exp\left(\sum_{l=0}^{x}(\theta - \beta_{jl})\right)}{\sum_{k=0}^{m} \exp \sum_{l=0}^{k}(\theta - \beta_{jl})}.$$

  Constraints on the parameters are necessary to ensure the identifiability of parameters. This model is also known as model PCM at one parameter or polytomous Rasch model.
- The Graded Response Model [12] is defined as:

$$\mathrm{Prob}(X_j \geq x \mid \theta) = \frac{\exp\left[(\theta - \beta_{jx})\right]}{1 + \exp\left[(\theta - \beta_{jx})\right]},$$

with $\beta_{j1} \leq \beta_{j2} \leq \cdots \leq \beta_{jm}$. For $x = 0$ and $x = m$, by definition $\text{Prob}(X_j \geq 0 \mid \theta) = 1$ and $\text{Prob}(X_j \geq m+1 \mid \theta) = 0$, respectively. The probability of having item score x is given by the difference

$$\begin{aligned}\pi_{jx\theta} &= \text{Prob}(X_j = x \mid \theta) = \text{Prob}(X_j \geq x \mid \theta) - \text{Prob}(X_j \geq x+1 \mid \theta) \\ &= \frac{\exp\left[(\theta - \beta_{ix})\right]}{1 + \exp\left[(\theta - \beta_{ix})\right]} - \frac{\exp\left[(\theta - \beta_{i(x+1)})\right]}{1 + \exp\left[(\theta - \beta_{i(x+1)})\right]}.\end{aligned}$$

36.2.2 Choice of the Latent Process Model

In this work, we suppose that this latent component $\theta(t)$ follows a markovian process of order 1. A consequence is that: $\forall t, t > 0$, $\Theta(t-1)$ and $\Theta(t+1)$ are independent conditional to the current $\theta(t)$, the latent value at time t. Graphically, our models are illustrated by Fig. 36.2a or 36.2b. One possible choice is to specify the distribution of $\Theta(t)$ such that:

$$\Theta(t) = c + \rho_L \Theta(t-1) + \varepsilon(t),$$

where $\varepsilon(t)$ is a gaussian white noise of variance σ^2 and ρ_L and c two real constants. It is easy to verify that this process is gaussian and defines a Markov chain of first order. Moreover, if $\mid \rho_L \mid < 1$, this process is stationary at the second order, of initial law the normal law with mean $\frac{c}{1-\rho}$ and variance $\frac{\sigma^2}{1-\rho_L^2}$ and the conditional probability of $\Theta(t)$ knowing $\Theta(t-1) = \theta(t-1)$ is gaussian of mean $c + \rho_L \times \theta(t-1)$ and variance σ^2. The joint law of variables $\Theta(1), \ldots, \Theta(T)$ is deduced easily:

$$\begin{aligned}g(\underline{\theta}) = &\frac{\sqrt{1-\rho_L^2}}{\sqrt{(2\pi)^T.\sigma^T}} \exp\left\{-\frac{1}{2\sigma^2}\left[(1-\rho_L^2)\left(\theta(1) - \frac{c}{1-\rho}\right)^2\right.\right. \\ &\left.\left.+\sum_{t=2}^{T}(\theta(t) - c - \rho_L\theta(t-1))^2\right],\right\}\end{aligned} \tag{36.1}$$

where $\underline{\theta} = (\theta(1), \ldots, \theta(T))$.

More general models can be defined [10].

36.3 Rasch Process Without Instrument nor Person Memory

Bousseboua and Mesbah [3], gave a natural extension of the Rasch model for binary items (items take values $x = 0$ or $x = 1$) to longitudinal data:

$$\pi(x_{ij}(t)/\theta_i(t)) = \frac{\exp(x_{ij}(t)(\theta_i(t) - \beta_j(t)))}{1 + \exp((\theta_i(t) - \beta_j(t)))}, \quad (36.2)$$

and assuming that $\beta_j(t) = \beta_j$ an invariance property of item parameters.

In a more general context, Fisher [5] introduced the constraint: $\theta_i(t) = \theta_i + \lambda(t)$ where $\lambda(t)$ is a fixed parameter that can be interpreted as a shift parameter. In his model the latent process $\theta_i(t)$ is a unidimensional process. It can be considered as a specific case of Bousseboua and Mesbah [3] model. Graphically, Bousseboua and Mesbah [3] model is illustrated in Fig. 36.2.

36.4 Rasch Process with Instrument Memory

Bousseboua and Mesbah [13] adapted the assumptions underlying a latent Rasch process to allow memory dependence between observations at two different times, without disturbing the main structure of the Rasch model for binary items (items take values $x = 0$ or $x = 1$). The distribution of the observed items conditional to the latent is obtained as:

$$p(x_j(1), \ldots, x_j(T)/\underline{\theta}) = \frac{\exp[\sum_{t=1}^{T} S(t)\theta(t) - \sum_{k=1}^{q} \beta_j R_j]}{\prod_{j=1}^{q} \prod_{t=1}^{T} (1 + \exp(x_j(t-1)(\theta(t) - \beta_j)))}. \quad (36.3)$$

Graphically, Bousseboua and Mesbah [13] model is illustrated in Fig. 36.2.

36.5 Joint Model for Instrument and Person Memories

In this section, we assume that the latent process $(\Theta(t) : 1 \leq t \leq T)$ is a latent $\mathscr{AR}(1)$ gaussian process. Similar assumption are usual in longitudinal modelling [7]. A graphical consequence of this assumption is that, in Fig. 36.2, there is no edge between Θ_{t+1} and Θ_{t-1}. It is known as the markov property. Moreover the distribution of Θ is gaussian, so the joint distribution of the $\Theta(t)$ for all t can be derived easily.

36.5.1 Practical Obtention of the Likelihood of the Joint Model

(1) Practical Obtention of the Distribution of the Joint Model for One Person

Let $(\underline{\mathbf{x}}(1), \ldots, \underline{\mathbf{x}}(T))$ be a trajectory of the observation process $(\underline{\mathbf{X}}(t) : 1 \leq t \leq T)$ relative to one individual only.

The process of observations $\left\{X_{i,j}\left(t\right)\right\}$ is supposed to have values in $\{1, 2, 3, \ldots, m\}$. The subscript i correspond to the patient, while j correspond to the item. The latent variable $\Theta_i\left(t\right)$ depends on the i patient only, it measures his level of HRQOL.

We note $\underline{\mathbf{X}}_i\left(t\right) = \left(X_{i,1}\left(t\right), \ldots, X_{i,q}\left(t\right)\right)'$ the answer vector of the patient i at time t and by $\pi_{jx_t\theta_t}$ the conditional probability $\mathbf{P}\left(X_{i,j}(t) = x_{i,j}(t)/\Theta_i(t) = \theta_i(t)\right)$, $i = \overline{1,n}$, $j = \overline{1,q}$ and $t = \overline{1,T}$. Let's note $\underline{\mathbf{X}}_i$ the answer vector of the patient i for the whole period.

The joint probability of the answer vector $\underline{\mathbf{X}}_i$ and of the unobserved latent path $\underline{\Theta}_i$ of the patient i, for the whole period $\{1, \ldots, T\}$ can be derived using the following assumptions:

- The latent process $(\Theta(t) : 1 \leq t \leq T)$ is a latent $\mathscr{AR}(1)$ gaussian process.
- The graphical model of the distribution is given by (Fig. 36.2).
- The conditional distribution $\pi_{jx_t\theta_t}$ of any observed item $X_j(t)$ at time t is a PCM or a GRM.

Let us note this joint probability, $p\left(\underline{\mathbf{X}}_i, \underline{\Theta}_i\right)$.

(2) Practical Obtention of the Likelihood of the Joint Model for One Person

The likelihood of the joint model for one person will be obtained directly from the joint probability of the observed and the unobserved by integrating over the unobserved latent.

$$p\left(\underline{\mathbf{X}}_i\right) = \int \cdots \int p\left(\underline{\mathbf{X}}_i, \underline{\Theta}_i\right) d\theta(1) \cdots d\theta(T). \tag{36.4}$$

The Eq. (36.4), as a function of the unknown parameters is the likelihood function. Its maximization will let us to obtain estimates with optimal inferential properties.

The likelihood derived from Eq. (36.4) will be function of all available data. Only available observations will be used. Maximization of the likelihood will allow us, in a first step, to get consistent estimation of all item parameters, the auto-correlation parameter of the AR (1) latent process and the constant c. Then, consistent prediction of the latent parameters will be obtained in a second step.

36.5.2 Practical Obtention of Maximum Likelihood Estimators

The marginal likelihood function obtained from Eq. (36.4) is a non-linear function of the vector of parameters $(\beta_{11}, \ldots, \beta_{1m}, \ldots, \beta_{qm}, c, \sigma^2, \rho_L)'$. There is no closed form for the exact maximum likelihood estimates (mles). The exact mles must be determined by numerically maximizing the exact log-likelihood function. Moreover, The expression of the exact log-likelihood function, contains integrals not analytically computable, which is often the case for similar latent variable model.

Newton-Raphson type algorithm with Gauss–Hermitte approximations of the integrals or Monte-Carlo Markov Chain (MCMC) algorithm are the most commonly used solutions.

36.6 Conclusion

Use of Rasch model as a measurement model to estimate latent parameters as a function of responses to a finite set of unidimensional questions is, nowadays, increasing. Fifty six years after the seminal paper of Georges Rasch [11], a great number of good monographies were published. In 1995, Fisher and Molenaar [5] edited an interesting monography devoted to Rasch model. More recently, Christensen et al. [4] edited a monography devoted to recent advance in Rasch models and their application in Health sciences.

Nevertheless, applying the Rasch model to longitudinal data is still an issue. Most of the times, it is done in two steps. In the first step, the data is used to estimate latent individual scores, as a function of dichotomous or polytomous item responses. In the second step, relationships of theses individual scores and external covariate are analyzed with classical methods (linear models). This two-step method use sequentially a measurement model (first step) and an analysis model (second step). More recently, latent regression methods, where both steps are included in one global model are proposed in different contexts.

In this work, we propose a new latent regression model, suitable to analyze longitudinal data. In our method, the measurement model is a Rasch model. The latent process is assumed to be an $\mathscr{A}\mathscr{R}(1)$ process. Moreover, our model take into account memorization effect of using the same questionnaire at different times (Fig. 36.1), but preserve the invariance over time property of the instrument (10): the value of an item parameter β_k is not a function of t.

Choice of the measurement model is an important step in the development of a HRQOL latent regression model. GRM or PCM for ordinal data GRM type models based cumulative logits link were preferred by Mac Cullagh [8], while PCM and Rasch Type models, based on adjacent logits are preferred by Anderson [2], mainly because they satisfy the sufficiency property for the latent parameter [1].

All these measurement models assume unidimensionality of the set of items.

Choice of the latent process model is another challenge. Of course, the proposed model is adaptable to when the latent component does not follow an AR(1)! The AR(1) model is, apart from the model of mutual independence of the latent components, the simplest model that we can specify. This model is interesting, because it is a model of short individual memory. The correlation between $\Theta(t)$ and $\Theta(t+s)$ will go to zero when s increase. One can imagine other kind of individual memory. Another work is in progress, where the latent process is assumed to be a long memory process [10], while the instrument is assumed without memory. The complexity of the model is due to the fact that for each specification of the latent distribution, one need to write the likelihood and to develop and adapted numerical program to get the estimates.

Longitudinal Health Related Quality of Life data, belongs to the family of real data that must be analyzed by latent variable models. In this work, we have proposed some ways of thinking and some models that we have applied to a complex real trial.

References

1. Andersen EB (1977) Sufficient statistics and latent trait models. Psychometrika 42(1):69–81
2. Anderson JA (1984) Regression and ordered categorical variables. J R Stat Soc Ser B (Methodol) 46:1–30
3. Bousseboua M, Mesbah M (2010) Processus de markov longitudinal latent rasch observable. Publ Inst Stat Univ Paris UV fasc 1–2
4. Christensen KB, Kreiner S, Mesbah M (2013) Rasch models in health. Wiley, London (Online Library)
5. Fischer GH (1995) Linear logistic models for change. In Fischer GH, Molenaar IW (eds), Rasch models. Foundations, recent developments, and applications. Springer, New York, pp 157–180
6. Horton M, Marais I, Christensen KB (2013) Dimensionality. Rasch models in health. Wiley, New York, pp 137–158
7. Masters GN (1982) A rasch model for partial credit scoring. Psychometrika 47(2):149–174
8. McCullagh P (1980) Regression models for ordinal data. J R Stat Soc Ser B (Methodol). 42:109–142
9. Mesbah M (2015) Analysis of a complex longitudinal health-related quality of life data by a mixed logistic model. Applied statistics in biomedicine and clinical trials design. Springer, Berlin, pp 313–328
10. Mesbah M, Senoussi R (2016) Long distance memory latent process for longitudinal data. Work in progress
11. Rasch G (1960) Probabilistic models for some intelligence and attainment tests. ERIC. University of Chicago Press, Chicago
12. Samejima F (1969) Estimation of ability using a response pattern of graded responses. Psycometrika monograph, 17
13. Urbain C, Galer S et al (2013) Pathophysiology of sleep-dependent memory consolidation processes in children. Int J Psychophysiol 89(2):273–283

Chapter 37
Development of the Estimation Method of Resident's Location Using Bioelectric Potential of Living Plants and Knowledge of Indoor Space

Hidetaka Nambo and Haruhiko Kimura

Abstract In Japan, an aging society is progressing rapidly, and the number of aged single-person households are also increasing. Therefore, to ensure residents' safety, a demand of monitoring is increasing. Generally, microphones or cameras are used for monitoring, however, it is hardly accepted to residents because their privacy will be violated by such devices. In this paper, we focused a living plant as a monitoring device. Living plants are easily accepted to residents. Furthermore, they have a property at bioelectric potential of a living plant will change affected by an activity of human around the plants. Moreover, according to the change of the potential, it is able to estimate a distance or a kind of activities of human. Therefore, we have studied to develop a method to use living plants for monitoring. However, we have found that monitoring by living plants has problems of an accuracy and a measuring distance. In this paper, we develop a monitoring method using living plans and a knowledge base of indoor space. The knowledge contains a layout structure of the space. Using both living plants and the knowledge base, we propose an improved monitoring method. And then, we report a result of experiment to confirm an accuracy of the method integrated content of the abstract in your paper should include the brief introduction of research intention, method, result and conclusion.

Keywords Plant bioelectric potential · Location estimation · Machine learning · Knowledge of layout

---

H. Nambo (✉) · H. Kimura
Graduate School of Natural Science and Technology, Division of Electrical Engineering and Computer Science, Kanazawa University, Kanazawa, Japan
e-mail: nambo@ec.t.kanazawa-u.ac.jp

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_37

37.1 Introduction

In Japan, there are severe problem that an aging society has been extremely progressed. For this reason, single-aged-person households are increasing. Furthermore, not only for aged person, there are many people who lives alone away from their family. Therefore, the demand to monitor resident's behaviors for their safety, security, and so on, is increasing. Usually, cameras or microphones are used to monitoring, however, these devices will violate resident's privacy. Furthermore, they will cause mental burdens on residents. In this study, we focus the plant bioelectric potential as a device to monitor resident's behaviors. In previous researches, it has been investigated that the plant bioelectric potential is affected by human's behaviors or activities [1, 4]. Therefore, we expect that we can monitor resident's behaviors by measuring the potential. Moreover, the plant bioelectric potential changes depending on the distance from human to the plant. In this paper, we propose the method to estimate a location of the resident in the room that many living plant are placed.

37.2 Previous Studies

Hirobayashi et al. [4] researched that the plant bioelectric potential is affected by human's behaviors. For example, when human is stepping near the plant, the potential changes interlinking with the step. Furthermore, Nomura et al. [3] showed that human behaviors, such as stepping, walking, opening doors and so on, can be distinguished by the difference of the plant electronic potential. However, these studies don't show that the relationship between the change of potential and a distance from the plant to human.

Jing et al. [2] proposed a method to estimate the distance from the plant to human with machine learning method using the change of the plant electric potential. In our previous research, based on Jing's paper, we investigated a location estimate method for a resident in the room [5]. In the research, we proposed the method to estimated which a resident is at any of the pre-defined points, using machine learning algorithm. As the result, although the accuracy was low, the location of a resident roughly estimated, and it is found that the plant bioelectric potential is able to apply for location estimation in indoor environment.

However, in the previous study, the estimated locations are limited by pre-defined points. The locations are not freely changed. The reason of the limitation is a classification algorithm is used in the previous study. In this study, based on the previous study, we propose the method to estimate a location of resident in a room using a regression algorithm to get rid of the limitation. Furthermore, when an estimated location is unlimited, it is considered that an estimation accuracy will be decreased. To avoid the decreases, we use a background knowledge about a layout of furniture in a room.

37.3 Experimental Environment

In this study, all measurement is done under the environment shown in Fig. 37.1. Two plants, P1 and P2, are located in the room that size is 3.45 m width, 5.75 m length, 2.60 m height. And, five measure points are set up, they are shown as M1–M5 in the figure. These points are used for measurement of training data. Their distance from two plants are shown in Table 37.1.

To measure bioelectric potential, we use GL900-4by GRAPHTEC Corporation (Fig. 37.2). All data in this study is measured at a sampling rate 500 Hz.

37.4 Estimation Method

In this chapter, a detail of the proposed method is described. The method consists from 3 parts, which are parameter extraction, learning and estimation. Each part is described in Sects. 37.4.1, 37.4.2 and 37.4.3 respectively.

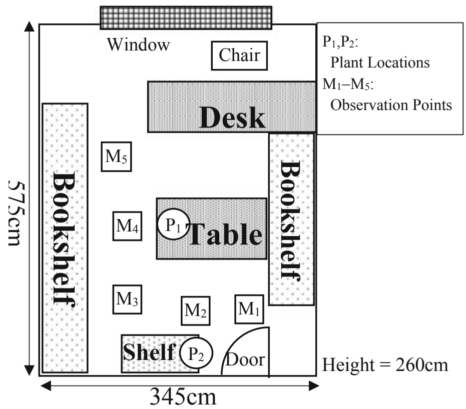


Fig. 37.1 The experimental environment

Table 37.1 Location of observation points and plants

Observation or living plant's point	X-coordinate	Y-coordinate
M1	260	475
M2	200	490
M3	140	430
M4	120	340
M5	110	260
P1	160	340
P2	200	530

Fig. 37.2 Measurement instrument; GRAPHTEC GL900-4

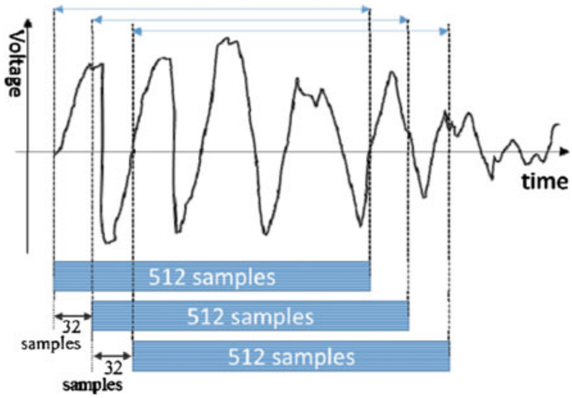


Fig. 37.3 Sampling period for the bioelectric potential

37.4.1 Parameter Extraction

All bioelectric potential is measured at sampling rate 500 Hz and transmitted to PC by GL900-4. Each data is time sequential data of a voltage. 512 sample data are regarded as 1 unit of analysis data. When PC receives 512 sample data, each data is processed every 32 sample points (Fig. 37.3). This 512 sample data is regarded as a block for analysis.

Each block is decomposed to smaller size for precise analysis. Figure 37.4 shows an original block and smaller blocks. In our method, not only smaller blocks but also an original block are target of analysis. The reason that we use various length of blocks is we expect to obtain various changes. When user stays near the plant for long time, the potential of the plant is affected for long time. On the other hand, when user stays for short time, just like passing by, the potential is affected for just a short time. Therefore, we have to observe various length of the potential. In our configuration of measurement, sampling rate is 500 Hz. In short, 500 sampling points represent the change in 1 s. We use 512 points as a block because we expect the potential change

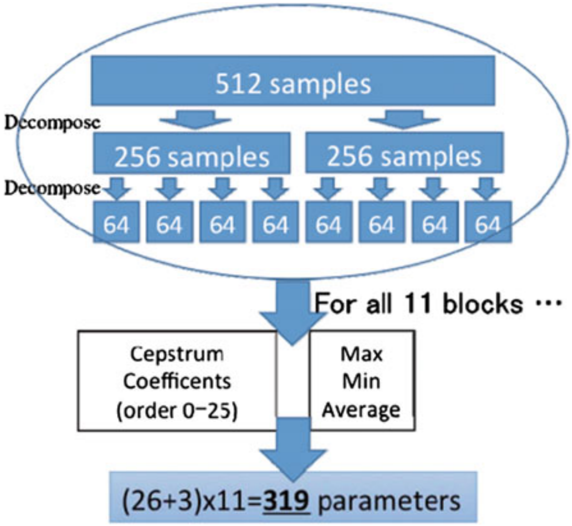


Fig. 37.4 Data decomposition from a unit of analysis

is within 1 s at most. For all original and decomposed blocks, cepstrum coefficients, maximum value, minimum value and average value are calculated. Cepstrum is a result of inverse-FFT of a power spectrum of a target signal. Here, let $G(\omega)$ be a spectrum of bioelectric potential signal in steady state, let $H(\omega)$ be a spectrum of affects to bioelectric potential by human behavior, and let $S(\omega)$ be a spectrum of the observed potential affected by human behaviors. With these definitions, we have the following equation.

$$|S(\omega)| = |G(\omega)||H(\omega)|. \tag{37.1}$$

Taking the log of both sides of Eq. (37.1), we have the following equation.

$$\log[|S(\omega)|] = \log[|G(\omega)|] + \log[|H(\omega)|]. \tag{37.2}$$

Previous paper reports that the effect by human behaviors on plant bioelectric potential appears at a lower band in the target signal [5]. In short, in frequency domain, $H(\omega)$ is distributed at lower frequency band than $G(\omega)$. Therefor, it is considered that we can obtain the feature of human behaviors by decomposing $S(\omega)$ to $H(\omega)$ and $G(\omega)$. To decompose the feature from the target signal, following procedures are conducted.

(1) Let as the original signal of potential.
(2) Obtain frequency components from FFT of.
(3) Calculate.
(4) Obtain cepstrum coefficients by calculating the inverse FFT of.

In this study, we calculate 26 cepstrum coefficients (order from 0 to 25).

For each block, 29 parameters, they are 26 cepstrum coefficients, max value, min value and average, are obtained. Totally, 319 parameters are obtained from a unit of analysis, because 11 blocks are obtained including an original block. We regard these parameters as one instance of the unit.

37.4.2 Learning Method

In this study, we use the multi layer perceptron algorithm as a learning method to build a regression model. We collect various bioelectric potential signals and analyze them. Then, we obtain an instance for a unit; each instance consists from 319 parameters as dependent variables, and the distance from observation point Mx to a living plant as target variables. Set of instances are input data of a learning method. We use Multi Layer Perceptron (MLP) Regressor on Weka version 3.7.12. As a result, we obtain a regression model to estimate a distance from a unit of bioelectric potential signals. An estimation model is built for each living plant, if there are two plants, two estimation models are obtained. This learning process is shown in Fig. 37.5.

37.4.3 Estimation Method

When estimating a distance, the parameters extracted from an instance are inputted to the estimation model obtained by the learning method. Then, the model outputs an estimated distance. In this study, it is supported that many living plant are located in

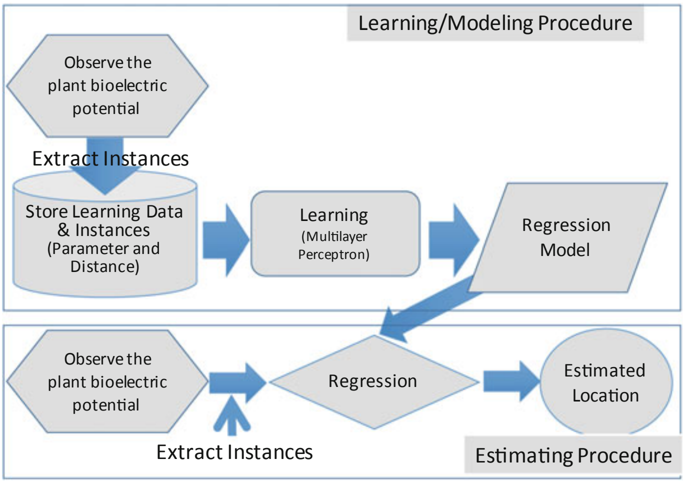


Fig. 37.5 Process flow of the learning/estimation method

a room. Therefore, two or more estimated distances are obtained from one instance. Then, we consider a circle that the center is the plant and the radius is a distance estimated by a corresponding estimation model.

According from an estimation model, the circumference of the circle is places where a resident may be existing. Using many models, we can consider that intersections of circles are more possible places.

However, not all place in a room is appropriate for existing. For example, if there is a table in a room, a resident will not be on the table usually. Therefore, parts of the circumference overlapped with obstacles in a room are excluded before considering intersections. To judge overlapping, we should prepare a knowledge about locations of obstacles in the room. This knowledge is one of background knowledge.

After considering obstacles, intersections will be obtained. If no intersections are obtained, it is resulted that estimation is failed. And, if only one intersection is obtained, a result of estimation is the location of it. Moreover, if two or more intersections are obtained, we should select one intersection as a result of estimation. As a selection strategy, we consider a continuity of time and location. The strategy is also one of background knowledge.

This estimation process is also shown in Fig. 37.5. In short, we use estimation models and background knowledge to estimate a location of a resident. The knowledge depends on an environment of a room. A detail of background knowledge is explained in Sect. 37.5.2.

37.5 Experiments and Considerations

Under the environment described in Sect. 37.3, we conducted estimation experiments to confirm a function of our method to estimate a location when a resident moves in the room.

37.5.1 Obtaining Data and Model

At first, we observe bioelectric potential signals to obtain learning data for model building.

When a test is walking around a point M1–M5 in Fig. 37.1, we observe the potential of P1 and P2 for 30 s. Furthermore, we observe when no person is in the room for 30 s.

These observations are repeated for 7 times. Totally, 210 s of potential signals are obtained for each measure point and a plant. In the same way, 210 s of potential signals are obtained for each plant when there is no person. All obtained data are sent to a PC and analyzed to extract parameters described in Sect. 37.4.1. Finally, 3171 instances are obtained for each point and one plant. There are 6 measure points (including no person) and 2 plants, then we obtained 19026 instances in total. After that, an estimation model is constructed using these instances. Using MLPRegressor on Weka, we obtain the models for each plant.

37.5.2 Location of Obstacles

To improve an estimation accuracy, we use an obstacle map as a background knowledge. The map is constructed from the environment of the room. We measured the location of desk, table and shelves, then we obtained the map shown in Fig. 37.6. From this map, we obtained the knowledge shown in Table 37.2. This table shows excluded regions that represented as (X1, Y1, X2, Y2), which means two diagonal vertexes. When considering a circumference of a circle, these regions shown in Table 37.2 are excluded.

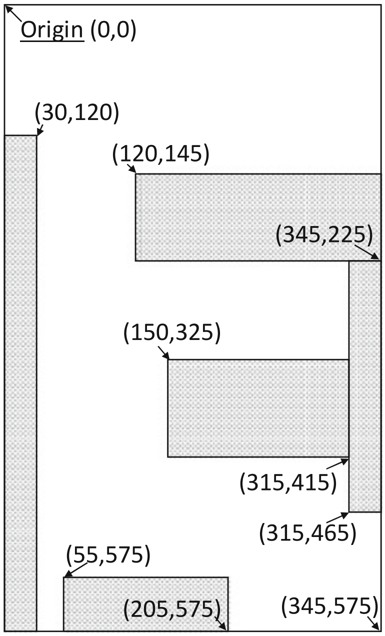


Fig. 37.6 The map of obstacles in the room

Table 37.2 Excluded regions in the room

	(X1, Y1, X2, Y2)
Excluded region	(0, 30, 30, 575)
	(120, 145, 345, 225)
	(150, 325, 315, 415)
	(315, 225, 345, 665)
	(55, 575, 205, 575)

37.5.3 Intersection Selection Strategy

In this experiment, two plants are located in the room. Therefore, the number of intersections of two circles are zero, one, or two. If the number is 0, it means estimation is failed. If the number is 1, the point of intersection is the location as the result of estimation. If the number is 2, one of two intersections is selected following the rules below.

Step 1 Select the intersection nearer from a previous estimated location. However, if a distance from the previous estimated location to the selected intersection is longer than D, no intersection is selected. D is a constant, that is calculated from an average of walking speed. Here, the previous estimated location is the location is the last result that estimated successfully. And, we assume the walking speed is less than 3 m/s.

Step 2 If there are no previous estimated location or if intersection is not selected in Step.1, select the intersection nearer from any observation point Mx. If distance of them are same, proceed Step 3.

Step 3 Select either of intersections randomly.

37.5.4 Location Estimation

Next, we conducted location estimation experiments using the model obtained in Sect. 37.5.1 and knowledge obtained in Sects. 37.5.2 and 37.5.4.

The plant bioelectric potential of P1 and P2 are observed when a testee moves in the room. We tested for 2 moving patterns.

(1) The testee stands at around M4 at first. When the observation starts, the testee moves to M1 through M3 and M2, and then returns to M4. The testee repeats this procedure 3 times.
(2) At first, the testee waits near the chair. 10 s after the observation starts, the testee moves to M1 through M5, M4, M3, and M2 for 10 s. After that, the testee goes out of the room from door and waits for 10 s.

For each pattern, the potential of P1 and P2 are observed for 30 s. Then, observed signals are analyzed and instances are obtained. Applying estimation models and knowledge, we get an estimated location for each instances.

Figures 37.7 and 37.8 show the estimated location for moving pattern 1. Figures 37.9 and 37.10 show the estimated point for moving pattern 2. In these figures, Figs. 37.7 and 37.9 show the X-coordinate of the estimated location in the room, and Figs. 37.8 and 37.10 show the Y-coordinate of them. To evaluate our method, we also conduct estimations without the obstacle map of the room. These results are shown in Figs. 37.11, 37.12, 37.13 and 37.14.

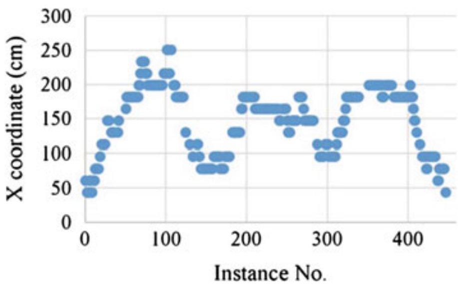


Fig. 37.7 X coordinate of the estimated location for the moving pattern 1

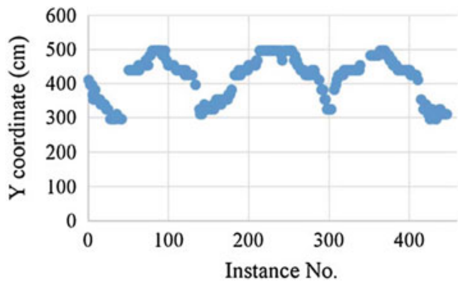


Fig. 37.8 Y coordinate of the estimated location for the moving pattern 1

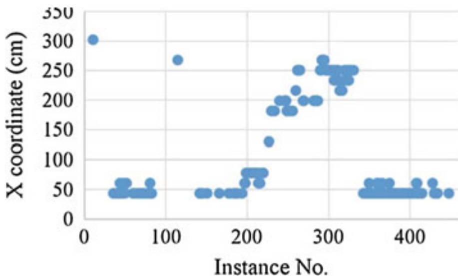


Fig. 37.9 X coordinate of the estimated location for the moving pattern 2

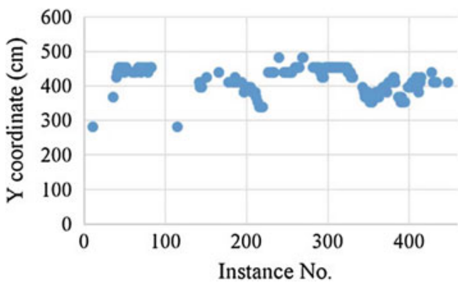


Fig. 37.10 Y coordinate of the estimated location for the moving pattern 2

Fig. 37.11 X coordinate of the estimated location without the obstacle map for the pattern 1

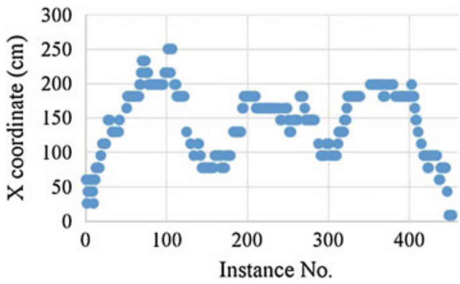


Fig. 37.12 Y coordinate of the estimated location without the obstacle map for the pattern 1

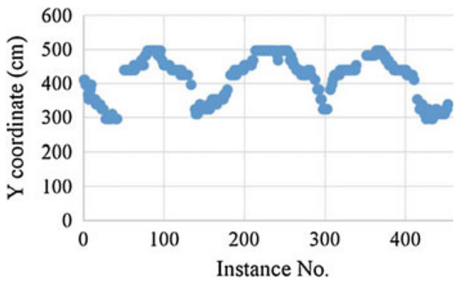


Fig. 37.13 X coordinate of the estimated location without the obstacle map for the pattern 2

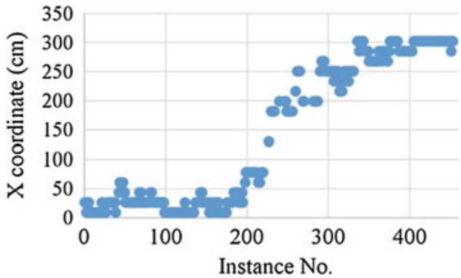
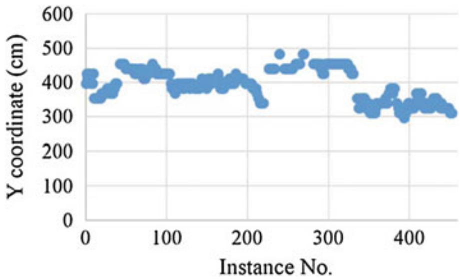


Fig. 37.14 Y coordinate of the estimated location without the obstacle map for the pattern 2

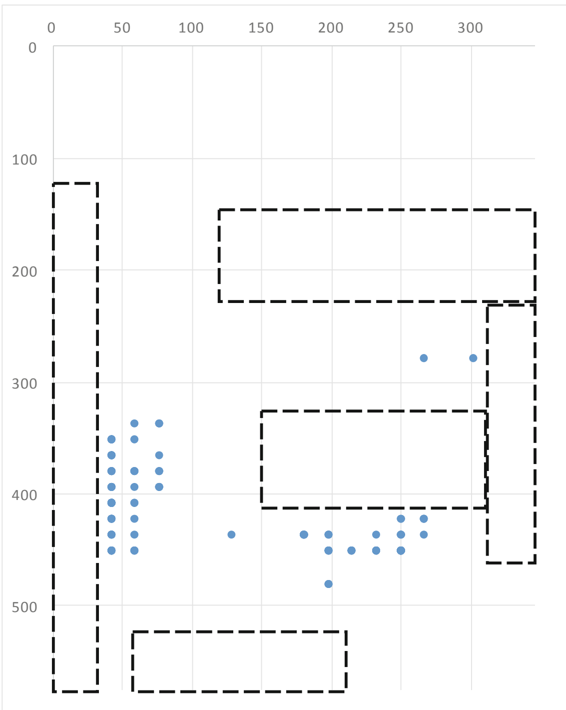


37.5.5 Considerations

According from Figs. 37.7, 37.8, 37.9 and 37.10, the shapes of the graphs represents the movement of the testee roughly. However, errors are striking while first 10 s and last 10 s in the result of estimation results for pattern 2. These periods correspond to when the testee doesn't move, or when he is out of the room. The bioelectric potential has a property that it is affected by a human's behaviors, and the effect depends on the distance to the human. If the distance is short, it is sensitive. However, if the distance is longer, it becomes insensitive. Therefore, it is difficult to estimate when a testee is far from the plant, and it is also difficult to distinguish the testee is far or he is not in the room.

Moreover, comparing the results with the obstacle map and the results without them, the effect of the map is different for pattern 1 or 2. Figures 37.12, 37.13, 37.14 and 37.15 show the result without the map. For pattern 1, Figs. 37.7, 37.8, 37.11 and 37.12, results are almost same, that means the effect of the map is small. Because the testee moves near the plant in the pattern 1, estimation works very well and the number of miss-estimation, for example, on the table, in the shelf, becomes small. On the other hand, for pattern 2, shown in Figs. 37.9, 37.10, 37.13 and 37.14, there are many case that the test locates far from either plant. In such case, the plant becomes insensitive, and estimation may not work well. Figures 37.15 and 37.16

Fig. 37.15 Estimated locations overlaid on the map for the pattern 2



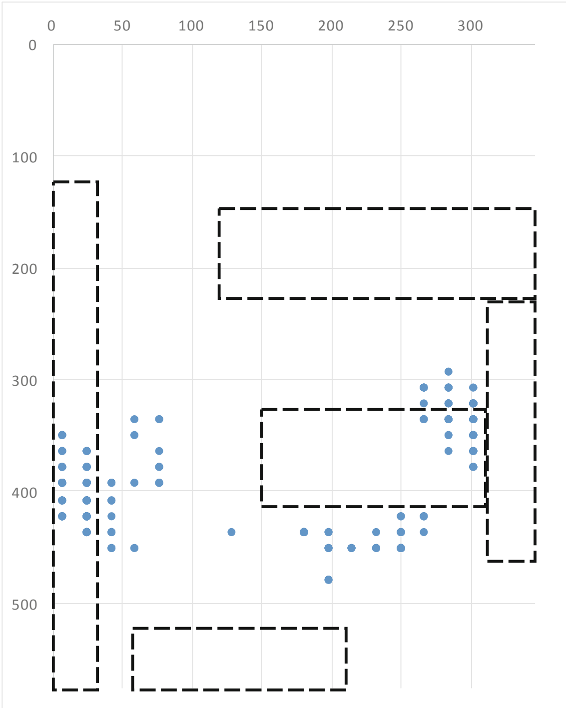


Fig. 37.16 Estimated locations without obstacle knowledge overlaid on the map for the pattern 2

show the estimated locations overlaid on the obstacle map. Comparing these figures, it is found that many estimated locations are excluded. Furthermore, miss-estimated locations are not only just removed but some locations moved to out of the obstacle region and relocated. In short, the effect of map can be confirmed.

Comprehensively, our proposed method works well, however, the accuracy is not enough. To improve the accuracy, we should solve the distance problem that the bioelectric potential becomes insensitive when a resident is far from a living plant. To solve the problem, it is a simple way to use more living plants in the room. However, it is unknown the optimal number of plants. In future works, we will investigate the optimal number. Furthermore, we will introduce another knowledge, for example, considering moving vector of a resident.

37.6 Conclusions

In this study, we proposed the method to estimate the location of a resident in the room. Placing two living plants and using the plant bioelectric potentials, our method made an estimation model by Multi Perceptron algorithm that is one of the machine learning method, and utilized the model for estimation. Furthermore, to improve accuracy, we used the knowledge about obstacles in the room, and a location history that is a previous estimated location. According to an evaluation experiment, it made obvious that our estimation method was able to estimate the location roughly. However, the accuracy of estimation was not enough. In future works, we should improve our method by using more plant and another knowledge.

Acknowledgments This work was supported by JSPS KAKENHI Grant Number 26350066.

References

1. Hirobayashi S, Tamura Y et al (2007) Monitoring of human activity using plant bioelectric potential. IEEJ Trans Sens Micromachines 127(4):258–259
2. Jin X, Nambo H, Kimura H (2014) Recognition of the distance between plant and human by plant bioelectric potential. In: Proceedings of the 15th APIEMS, Jeju, Korea pp 602–606
3. Nomura K, Nambo H, Kimura H (2014) Development of basic human behaviors cognitive system using plant bioelectric potential. IEEJ Trans Sens Micromachines 134(7):1–6
4. Oyabu T, Katsube T (2009) Plant bioelectric potential and communication. Kaibundou pp 1–32
5. Shimbo T, Fujii M et al (2004) Statistical analysis of plant bioelectric potential for communication with humans. IEEJ Trans Sens Micromachines 124(12):470–475

Chapter 38
Asymmetric Information Effect on Transshipment Reporting Strategy

Yi Liao, Wenjing Shen and Ben Lev

Abstract Lateral transshipments in multi-echelon stochastic inventory system imply that locations at the same echelon of a supply chain share inventories in some way, in order to deal with local uncertainties in demands. While a large body of research studies inventory transshipment issues, few papers have considered the effect of information on transshipment reporting decisions. We analyze the transshipment decisions after demand realization under a decentralized setting with asymmetric information concerning demand. In this research, the shortage demand information at one retailer is not public and the shortage retailer may manipulate this number in order to obtain the optimal transshipment amount. We not only demonstrate that the shortage retailer can distort the actual shortage number to improve its profit, but also identify when to use under-reporting or over-reporting policy. Furthermore, we also explore the reporting policy when the surplus retailer only informs the shortage retailer its surplus inventory distribution or mean and variance.

38.1 Introduction

Transshipment is a widely implemented policy when a stock out occurs at a retail store, while another retailer has leftover stocks. For example, it is an almost daily occurrence that a customer may desire a certain automobile with a specific color while the dealership of choice does not have it in stock as it is impractical for any dealership to carry a stock of the entire range of models and colors. A common solution to a shortage problem such as this is known as dealer trade, which allows the dealer to arrange transshipment at the manufacturers' wholesale price from another local dealer. It is obvious that transshipment across locations helps retailers improve

Y. Liao (✉)
School of Business Administration, Southwestern University of Finance and Economics, Chengdu 611130, People's Republic of China
e-mail: yiliao@swufe.edu.cn

W. Shen · B. Lev
Lebow College of Business Drexel University, Philadelphia, PA 19104, USA

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_38

customer service and contributes towards a better match between supply and demand. Nevertheless, transshipment may not be successfully arranged all the time. It is well understood that appropriate transshipment decisions made under central coordination can lead to increased supply chain profit. In the case of automobile sales, though most dealerships are associated with major automobile manufactures, such as GM, Toyota, etc., they operate independently. When a central coordination mechanism does not exist, transshipment decisions are made locally by individual firms to further the best interest of each individual party. Meanwhile, any unmet customer may switch from one dealership to another until her/his desired car is found. Furthermore, selling directly to a customer is usually more profitable than transshipping to the shortage retailer. Clearly, any transshipment agreement and customer switching behavior are likely to interact with each other. Thus, any retailer with extra stock may strategically reserve some inventory to achieve more profit.

From [15], transshipment decisions based on symmetric information are analyzed, where both retailers have the full access to all the necessary and accurate information, such as surplus inventory or stock shortage. In order to maximize its own profit, it is common that competing retailers do not share demand information with each other. In particular, it is a natural tendency for business entities to keep their important business information confidential. In our research, we consider a practical case that information is not symmetric any more. If this is the case, how will this information structure affect transshipment decisions? Especially, the transshipment quantity requested by a shortage retailer is also an indicator of the amount of potential switching demand. Therefore, it is possible that the shortage retailer may manipulate the behavior of the surplus retailer with this information. Let's take a look of this interesting phenomena by a 2-retailer example, where retailer i has some extra stocks and retailer j is out of stock after overall demands are realized and the local demands are fulfilled. Then, the shortage retailer j requests an amount of q_{ij} to be transshipped from the surplus retailer i which determines the number of transported quantity of $\bar{q}_{ij}, \bar{q}_{ij} \leq q_{ij}$.

Obviously, retailer j's request amount of q_{ij} has two effects: on one hand, if q_{ij} is too large, retailer i may think that a large number of customers who cannot obtain the products from retailer j may switch to buy at its store, inducing it to reserve more inventory. In order to maximize its profit, it is quite possible that q_{ij} may be deliberately deviated from the actual shortage amount, especially the number of unmet customers is greater than the extra products. However, one the other hand if q_{ij} is too small, it may not receive enough inventory to satisfy the residual demand.In either case, the shortage retailer faces a risk of not receiving a significant transshipment amount. It would be worthwhile to explore when the retailer with unsatisfied demand has an incentive to inflate or deflate the amount of transshipment necessary from the retailer with extra inventory, in an attempt to increase its own profit after demand is realized.

Since this research is the first step to explore the shortage retailer's reporting policy, we start with the assumption that retailer i naively believes that q_{ij} is the actual shortage amount at retailer j in our analysis. There is no doubt that the shortage retailer may take advantage of this trust and request the optimal transshipment amount to maximize its own profit. However, on the other hand, in reality, the surplus retailer may not release the complete surplus inventory information to the shortage retailer. In some instances, the shortage retailer develops its own knowledge of the surplus amount which forms the basis for its transshipment reporting policy. It would be interesting to investigate how this kind of asymmetric information affects the effectiveness of transshipment policies and practices. In the circumstance of asymmetric information, we limit our attention on two retailers and each retailer attempts to maximize its own profit. We mainly focus on the policies of the retailer after demand is realized, addressing the following issues:

1. What is the optimal transshipment policy for the retailer with surplus stock when information is privately held? How much inventory should be kept in reserve and how much should be transshipped if only the shortage distribution is known?
2. Does the phenomenon of over-reporting or under-reporting of shortage exist?
3. What is the impact of such information distortion on profits? Should such over-reporting or under-reporting of transshipment requests be encouraged?

38.2 Literature Review

The current literature on lateral transshipments focuses on shipments among multiple partners in the same echelon of a supply chain. In order to maximize its own profit, each partner may resort to transshipment decisions for dealing with stockouts after demand is realized. By transshipping inventories among themselves after observing demand, all partners and the supply chain can improve system profitability by increasing the overall demand fill rate, as well as by reducing overstocking costs. The existing literature generally accounts for stockholding, shortage, transshipment and production related costs. A seminal work that considers a two-location transshipment problem under uncertain demand is found in Gross [4], who derived an optimal policy for a system in which replenishment and transshipment policies are implemented together at the beginning of each period. The corresponding single-period two-location problem and its N-location extension are studied by Krishman and Rao [11]. In their research, they develop a periodic review, single-echelon model in which transshipment between lower echelon stock facilities is allowed with zero replenishment and transshipment lead times. These assumptions are a major limitation of their work, since both the transshipment and replenishment policies generally depend on stock on hand and orders in transit. The multi-period, multi-location scenario is examined by Karmarkar and Patel [10] and Showers [16]. Our research is closely related to the literature focusing on a decentralized system in which different partners evaluate their own profit/cost individually and play a non-cooperative game. In order to maximize profit, each partner uses transshipment to deal with potential shortage after demand is realized. Typical literature studies equilibrium behavior and aims at designing a coordination mechanism to increase supply chain profit. One of the first papers to consider a decentralized system is Rudi and Pyke [14], and its extension, Hu et al. [8]. Both papers show the uniqueness of Nash equilibrium in order quantities for the two retailers, and discuss the existence of a coordinating transshipment price. Anupindi et al. [1] and Granot [6] studied a cooperative game in transshipment stage but non-cooperative game in order stage. Zhao et al. [18] used a continuous review model to prove the optimal transshipment policy for the decentralized dealer network. Huang and Sošić [9] studied a repeated inventory sharing game with N retailers and profit of transshipment is distributed among retailers by dual allocation. Since transshipment decisions are made using shortage and surplus information, the existence of an information sharing protocol plays a key role in a decentralized supply chain. In fact, much of recent research focuses on how information can be used to improve overall supply chain performance. One stream of research in this respect examines the asymmetric in formation of customer demands and another stream focuses on the asymmetry of cost information. In the first in this area study, Bourl et al. [2] considered the advantage of information sharing between the manufacturer and retailer, when the disparity in their order cycle lengths is large. Gavirneni et al. [5] provided a model with a finite capacity supplier following an (s, S) policy. By studying the holding and penalty costs, they compare the benefits of information sharing about the retailer's inventory level under various types of demand distribution. Cachon and Fisher [3] studied the benefits of sharing information in one supplier, as well as N-retailer systems and conclude that implementation of information technology plays a significant role in accelerating and smoothing the physical flow of goods. Lau and Lau [12] outline the necessity and practicality of using asymmetric information in stochastic supply chains, which leads to a more realistic two echelon supply-chain gaming model. They examine a dominant retailer's operating policy under deterministic demand when the manufacturer's cost information is not shared. They propose a quantity discount scheme and derive an optimal markup, which appear to be quite effective. Examples of cost information asymmetry are provided by Ha [7] and Suck [17]. In a more recent study, Liu and Cetinkaya [13] considered a buyer-driven channel and study the difference between full information and incomplete information sharing scenarios of the supplier's costs. They conclude that sometimes information asymmetry leads to higher profit, without the leadership position of a supply chain contract.

In this paper, we consider a single-product, two-location model under a decentralized frame. We find that transshipment decisions are affected by asymmetric information issue. In some circumstances, the shortage retailer can take advantage of information asymmetry to improve its profit. In our analysis, we focus on the optimal reporting-policy (under-reporting or over-reporting) in achieving maximum profit, when information is not shared completely among the parties. In the remainder of the paper, we first propose a model that incorporates asymmetric information in Sect. 38.3. Then, we analyze the optimal transshipment reporting decisions under decentralized control in Sect. 38.3.1. The paper is summarized in Sect. 38.3.2. All the proofs are presented in Appendix.

38.3 Model Assumptions

We consider a single period model where two retailers ($i \neq j \in \{1, 2\}$) sell a common product to their independent markets with random demand D_i and D_j, respectively. We label D_i and D_j as "local demands". All the relevant parameters for retailers i and j can be asymmetric.

The events take place as follows. At the beginning, before observing the respective demands, the inventory order quantities Q_i and Q_j are simultaneously determined by retailers at both locations. Then the random demands Q_i and Q_i are realized, inventory at each location is used to satisfy local customer demand.

The next stage is the transshipment stage. Sticking to the example used in the earlier discussion, we still assume that retailer j, is short of inventory (referred to the "shortage retailer"), and the other retailer, i.e. retailer i, has surplus (referred to the "surplus retailer"). Subsequently, retailer j requests a quantity q_{ij} from retailer i. Obviously, q_{ij} is not necessary to be $\min\{D_j - Q_j, Q_i - D_i\}$ since retailer may inflate or deflate the actual number in order to improve its profit. Retailer i eventually decides the number of transshipped products $\overline{q}_{ij} \leq q_{ij}$ to retailer j. After q_{ij} units of inventory are transshipped to retailer j, they are used to meet the remaining customer demand at this location. If there is still any unfilled demand at retailer j, a random fraction A_i of this remaining demand will switch to retailer i, which we labeled as "switching demand". We assume that the faction A_i has a cdf $F_i(.)$, a pdf $f_i(.)$ with supports $[m, n]$, $0 \leq m \leq n \leq 1$, and is independent of D_i and D_j. F_i is twice differentiable and is a strictly increasing function. Retailer i then uses its own inventory available at this time (i.e., $Q_i - D_i - \overline{q}_{ij}$) in order to satisfy these switching customers.

At the beginning, retailer i pays a unit cost of c_i for each unit of inventory ordered before demand is realized, and subsequently receives a revenue of r_i for each unit sold to its local customers or to switching customers from retailer j. For each unit of inventory transshipped from retailer i to retailer j, retailer i receives transshipping price p_{ij} from retailer j, and pays τ_{ij} as the transportation cost. Any inventory left at the end of the period has a salvage value of s_i per unit. Furthermore, retailer i incurs a penalty cost of l_i for each unit of unsatisfied local demand. We assume that there is no penalty cost charged if retailer i cannot satisfy switching demand. It is always desirable if customers can satisfy their demands from another retailer when they cannot find the product at their preferred store, which may reduce the lost sale cost of their favored retailer. But if customers cannot find the product at the alternative store, they tend to feel more disappointed with their retailer of first choice. Therefore, our assumption above appears to be reasonable and hence a lost sales penalty is assessed to the customers' preferred retailer.

We summarize the notations adopted as follows (Fig. 38.1):

Q_i: inventory level at retailer before demand is realized;
D_i: local demand at retailer i with $cdf = G_i(.)$ and $pdf = g_i(.)$;
c_i: unit purchasing cost for retailer i;
r_i: unit revenue for retailer i;

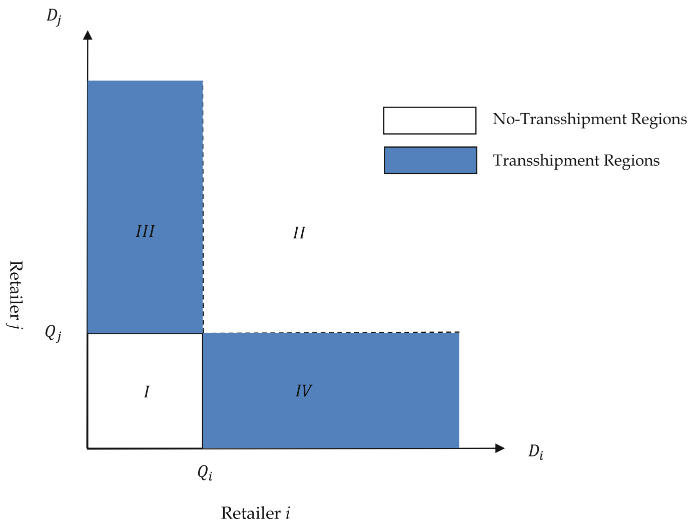


Fig. 38.1 Inventory scenarios

s_i:	unit salvage value for retailer i;
l_i:	unit unsatisfied demand penalty cost for retailer i;
p_{ij}:	unit transshipment price retailer j pays to retailer i;
τ_{ij}:	unit transshipment cost of firm i for transshipment from retailer i to retailer j;
A_i:	fraction of unsatisfied demand switching from retailer j to retailer i with $cdf = F_i(.)$ and $pdf = f_i(.)$;
q_{ij}:	transshipment quantity requested by retailer j;
$\overline{q}_{ij}$:	actual transshipment quantity from retailer to retailer j;
S_i^+:	retailer i's surplus inventory amount;
S_j^-:	retailer j's shortage demand amount;
$H_i^+(.)$:	the distribution function of firm i's surplus inventory S_i^+.
I:	if $D_i \leq Q_i$ and $D_j \leq Q_j$, then both retailers have inventory surplus and no transshipmentis necessary.
II:	if $D_i > Q_i$ and $D_j > Q_j$, then both retailers face inventory shortage and no transshipment occurs.
III:	if $D_i \leq Q_i$ and $D_j > Q_j$, then retailer i has inventory surplus and retailer j faces shortage. Here a transshipment decision needs to be made by retailer i.
IV:	if $D_i > Q_i$ and $D_j \leq Q_j$, then retailer j has inventory surplus and retailer i faces a shortage, requiring a transshipment decision by retailer j.

38.3.1 Transshipment Reporting Strategy

In this section, we analyze the decisions after demand realization under a decentralized setting with asymmetric information. Hence, when the transshipment decision is needed (one retailer has the surplus and the other has the shortage), the surplus retailer i knows only his extra inventory $Q_i - D_i$ but not the deficit $D_j - Q_j$ of shortage retailer j. At this time, retailer i believes that q_{ij} is the true amount of the shortage at retailer j and retailer i informs retailer j that the surplus amount $S_i^+ = Q_i - D_i$. In our analysis, we still assume that both retailers are rational and make transshipment decisions based on transshipment rationing [15]. For any given q_{ij} that retailer j requests, firm i determines the best transshipment quantity $\overline{q}_{ij} \le q_{ij}$. Since retailer i completely trusts the shortage amount reported by retailer j, the transshipment decision is exactly the same as in the symmetric situation, although it may not be the optimal transshipment quantity for retailer i. Knowing the response of retailer i for each given q_{ij}, we examine the decision of retailer j. Retailer j chooses q_{ij} to maximize profit:

$$\prod_j = \max_{q_{ij}}(-p_{ij}\overline{q}_{ij}(q_{ij}) + (r_j + l_j)\min(\overline{q}_{ij}(q_{ij}), D_j - Q_j)).$$

The first term is the transshipment cost paid by retailer j and the second captures the revenue generated from transshipment. Since retailer j has all the demand information and enjoys the trust of retailer i, it can take advantage of such trust in order to maximize its own expected profit by reporting the optimal shortage amount. The following result indicates the nature of the transshipment decision in such a situation and presents the optimal reported shortage amount for retailer when the unmet demand is greater than the amount of surplus.

Corollary 38.1 *If retailer i believes that q_{ij} is the amount of shortage at retailer j and discloses the amount of surplus as $Q_i - D_i$, if $Q_i - D_i < D_j - Q_j$, $q_{ij} = \overline{q}_{ij} = Q_i - D_i$.*

As we discussed in the previous analysis, once the shortage is greater than the surplus, retailer j has some concerns. If retailer j discloses the real unmet demand, retailer i may just transship small portion of the requested transshipment amount, even not transship any extra stock since it expects that the entire surplus inventory may be absorbed by switching customers. Our research indicates that the shortage retailer i.e. retailer j uses the under-reporting strategy to get its desired transshipment amount i.e. $Q_i - D_i$ and improve its profit by taking advantage of retailer's trust and asymmetric information. The difference between the profits of retailer j with under-reporting strategy and without under-reporting strategy can be regarded as the value of information and trust. Next, we turn to consider the situation that the surplus amount of retailer i is greater than the shortage from retailer j, i.e. $Q_i - D_i > D_j - Q_j$.

Corollary 38.2 *If retailer i believes that q_{ij} is the amount of shortage at retailer j and discloses the amount of surplus as $Q_i - D_i$, if $Q_i - D_i \ge D_j - Q_j$, then retailer*

j is indifferent between reporting $q_{ij} = D_j - Q_j$ and $q_{ij} = \frac{Q_i - D_i - (D_j - Q_j)(1 - z_i^*)}{z_i^*}$. Thus, $\overline{q}_{ij} = D_j - Q_j$. $\int_m^{z_i^*} (1-a) f_i(a) da = \frac{r_i + \tau_{ij} - p_{ij}}{r_i - s_i}$

Since $q_{ij} = \frac{Q_i - D_i - (D_j - Q_j)(1 - z_i^*)}{z_i^*} \geq Q_i - D_i$, it is possible that retailer j manipulates retailer i's behavior by over-reporting the shortage, in the process of receiving the same amount of transshipment after retailer i's rationing decision. Since this over-reporting decision does not influence the transshipment decision, it does not have any real impact on the retailers' profits. Though there is no difference at the profit level for retailer j, over-reporting strategy is a good weapon to mislead the competitor. When the shortage is less than the surplus, retailer i is willing to transship the entire shortage amount, thus, indicating that accurate shortage reporting can be advantageous for retailer j because this strategy may increase its credit without hurting its current profit.

According to Corollaries 38.1 and 38.2, if retailer j knows the exact surplus amount $Q_i - D_i$ of retailer i, its reporting strategy is slightly different when his shortage is more or less than the surplus. When shortage is more than surplus, if retailer j reports the true amount of shortage, the results from Shen et al. [15] instruct retailer i not to transship all available inventory in anticipation of switching demand. Therefore, retailer j will under-report the amount of shortage. However, retailer j does not want to report too little shortage either, since retailer i naively believes the report of retailer j and Corollary 38.1 indicates that retailer i should ship all the necessary to satisfy retailer j. Consequently, the best strategy is to report exactly $Q_i - D_i$ and retailer i will transship all available stocks. Such under-reporting action helps retailer j to obtains many as possible inventory, and the situation becomes the same as in [14] without customer switching.

Oppositely, when shortage is less than surplus, retailer i is willing to transship all shorted amount of retailer j, thus telling the truth is good enough for retailer j. Of course, retailer j can also exaggerate his shortage to receive the same amount of transshipment after the rationing decision of retailer i. Since this over-reporting action does not influence transshipment decision, it does not have a real impact on profit.

In the following, we consider a more general case, where retailer i does not disclose information on the amount of shortage. Instead, retailer j only knows the distribution of $Q_i - D_i$ with cdf $H_i(.)$. When the retailers' inventory decisions are observable, $H_i(.)$ can be obtained from the distribution of $Q_i - D_i$, $D_i < Q_i$. For any given q_{ij} that retailer j requests, retailer i determines the best transshipment quantity $\overline{q}_{ij} \leq q_{ij}$. This leads to the result shown below:

Corollary 38.3 *If retailer i believes that q_{ij} is the amount of shortage at retailer j and retailer j only knows the distribution cdf $H_i(.)$ of the surplus amount $Q_i - D_i$, then letting $q_{ij}^* = H_i^{-1}(1 - z_i^*)$, $q_{ij} = \min(q_{ij}^*, D_j - Q_j)$.*

When retailer j does not know the exact surplus amount, it cannot decide on the value of q_{ij} based on $Q_i - D_i$ as in Corollaries 38.1 and 38.2. However, the intuition implied by Corollaries 38.1 and 38.2 still applies. Retailer j now considers two possibilities: if the surplus amount is more than the shortage, then as indicated by Corollary 38.2, there is no need to over-reporting. If, on the other hand, the surplus amount is less than the shortage, then, as indicated by Corollary 38.1, retailer j has an incentive to under-report the shortage. Therefore, when the surplus amount is unknown to retailer j, it would like to implement under-reporting the shortage when it is relatively large. It is also interesting that we identify there exists a constant number i.e. $q_{ij}^* = H_i^{-1}(1 - z_i^*)$ which is independent of $D_j - Q_j$, such that when $D_j - Q_j$ is greater than its value, the requested transshipment amount of retailer j is always this number.

According to Corollary 38.3, retailer j does not adopt the over-reporting strategy once retailer i only disclose its surplus inventory distribution information. Additionally, this result is not restricted by the distribution type of the surplus amount. Although our analysis provides the optimal reporting strategy for the shortage retailer, i.e. retailer j in this study, it is hard to implement reporting strategy completely in practice as the distributional information of the surplus inventory is not easy to find. Sometimes all the shortage retailer's available information is the certain parameter's value of the surplus inventory's distribution. The purpose of subsequent result is to help the shortage retailer make reporting decisions once the mean and the variance of the surplus inventory meet certain criteria.

Corollary 38.4 *If retailer i believes that q_{ij} is the amount of shortage at retailer j and retailer j only knows the distribution of the mean and variance σ^2 of the surplus amount $Q_i - D_i$, when $\mu - (D_j - Q_j) > \sigma\sqrt{\frac{z_i^*}{1-z_i^*}}$, then $q_{ij} = D_j - Q_j$.*

It is quite clear that Corollary 38.4 gives the shortage retailer a powerful tool when reporting decision is needed. Generally, it is very difficult to capture all the information of the surplus inventory. With the aid from Corollary 38.4, the shortage retailer doesn't have to under or over report the shortage amount if the shortage amount is less than the mean and the gap between them is greater than a constant number. Although, intuitively, the shortage retailer doesn't have to manipulate the shortage number when it is quite small, Corollary 38.4 furthers this by providing a more handful result.

38.3.2 Conclusions and Discussion

In this study, we consider a single-period, two-retailer transshipment model without any centralized coordination. Different from the existing literature, we incorporate asymmetric information issues in the model and primarily focus on how the shortage retailer uses the optimal reporting-policy (under-reporting or over-reporting) to obtain the maximum profit. Assuming that the surplus retailer believes the shortage retailer's transshipment request amount, we not only demonstrate that the shortage retailer may manipulate the actual shortage number to improve it profit, but also identify when to use under-reportingor over-reporting policy. Furthermore, we also explore the reporting policy when the surplus retailer only informs the shortage retailer its surplus inventory distribution or mean and variance. Certainly, we can absorb some important issues in our future research, such as the surplus retailer's trust level, i.e., the surplus retailer may only partially believe the shortage retailer's request number.

References

1. Anupindi R, Bassok Y, Zemel E (2001) A general framework for the study of decentralized distribution systems. Manuf Serv Oper Manag 3(4):349–368
2. Bourland KE, Powell SG, Pyke DF (1996) Exploiting timely demand information to reduce inventories. Eur J Oper Res 92(2):239–253
3. Cachon GP, Fisher M (2000) Supply chain inventory management and the value of shared information. Manag Sci 46(8):1032–1048
4. Federgruen A, Heching A (2002) Multilocation combined pricing and inventory control. Manuf Serv Oper Manag 4(4):275–295
5. Gavirneni S, Kapuscinski R, Tayur S (1999) Value of information in capacitated supply chains. Manag Sci 45(1):16–24
6. Granot D (2006) A three-stage model for a decentralized distribution system of retailers. Oper Res 51(5):771–784
7. Ha AY (2001) Supplier-buyer contracting: asymmetric cost information and cutoff level policy for buyer participation. Nav Res Logist 48(1):41–64
8. Hu X, Duenyas I, Kapuscinski R (2007) Existence of coordinating transshipment prices in a two-location inventory model. Manag Sci 53(8):1289–1302
9. Huang X, Sošić G (2010) Repeated newsvendor game with transshipments under dual allocations. Eur J Oper Res 204(2):274–284
10. Karmarkar US, Patel NR (2006) The one-period, n-location distribution problem. Nav Res Logist Qu 24(4):559–575
11. Krishnan K, Rao V (1965) Inventory control in N warehouses. J Ind Eng 16(3):212
12. Lau AHL, Lau HS (2005) Some two-echelon supply-chain games: improving from deterministic-symmetric-information to stochastic-asymmetric-information models. Eur J Oper Res 161(1):203–223
13. Liu X, Cetinkaya S (2009) Designing supply contracts in supplier vs buyer-driven channels: the impact of leadership, contract flexibility and information asymmetry. Iie Trans 41(8):687–701
14. Rudi N, Pyke DF (2001) A two-location inventory model with transshipment and local decision making. Manag Sci 47(12):1668–1680
15. Shen W, Hu X, Liao Y (2010) Lateral transshipment with customer switching. Northeast DSI conference. Springer, Berlin, pp 815–831
16. Showers JL (1979) A multiperiod multilocation inventory model with transshipments. Ph.D. thesis, Columbia University
17. Sucky E (2006) A bargaining model with asymmetric information for a single supplier-single buyer problem. Eur J Oper Res 171(2):516–535
18. Zhao H, Ryan JK, Deshpande V (2008) Optimal dynamic production and inventory rransshipment policies for a two-location make-to-stock system. Oper Res 56(2):400–410

Chapter 39
Metasynthesis-Based Intelligent Big Data Processing Paradigm

Ziqiang Zeng, Xinxin Xu and Jonathan Shi

Abstract This research aims to establish a methodology of metasynthesis-based intelligent big data processing paradigm which works based on the mechanisms of metasynthesis-architecture, metasynthesis-technology, and the principle of metasynthesis-intelligence. The proposed method will achieve the ability of intelligent data acquisition, data identification, data structure design, data analysis, and make decisions automatically and intelligently based on integrated big data processing technologies, decision making modeling methods, and intelligent algorithms. The human involvement, societal characteristics, dynamic characteristics, and uncertainty are also considered in this study. The current research status is analyzed including the big data architectures, big data processing systems, big data management, big data application. In order to deal with the complexity of big data system and establish an intelligent big data processing problem-solving methodology, an idea of "3M" structure of metasynthesis is proposed. The methodology framework is built based on the academic thoughts of metasynthesis. The application prospects for this methodology is discussed for future research.

Keywords Meatasynthesis-based intelligent · Big data · Processing paradigm · M-architecture · M-technology · M-intelligence

---

Z. Zeng · X. Xu (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: xinxinxu@scu.edu.cn

Z. Zeng
Smart Transportation Applications and Research Laboratory, Department of Civil and Environmental Engineering, University of Washington, Seattle, WA 98195, USA

X. Xu
School of Tourism and Economic Management, Chengdu University, Chengdu 610106, People's Republic of China

J. Shi
Department of Construction Management, Louisiana State University, Baton Rouge, LA 70803, USA

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_39

39.1 Introduction

It is already true that big data has drawn huge attention from researchers in information sciences, policy and decision makers in governments and enterprises [5]. As the speed of information growth exceeds Moore's Law at the beginning of this new century, excessive data is making great troubles to human beings. Nowadays, data comes from sensors, lab experiments, simulations, individual archives, enterprise and Internet in all scales and formats. This data flood has outpaced our capability to process, analyze, store and understand these datasets. Such rapid expansion is also accelerated by the dramatic increase in acceptance of social media and networking applications. The trillions of connections on the Internet will generate a huge data ocean, and valuable information must be discovered from the data to help improve quality of life and make our world a better place.

In fact, the current researches on big data are concentrated on the fields including big data architectures [3], big data processing systems [10, 23, 25, 28], big data management [6, 7, 9, 11], and big data applications and modeling [2, 8, 18, 26], MapReduce optimization [12, 13, 15] and so on. All of these studies not only provide novel ideas and state-of-the-art techniques in the field, but also stimulate future research in the sustainable environment.

However, two paths lie before us in the big data era: a 'hard path' that will rely almost exclusively on the development of computer and internet technologies (hardware and software) to achieve the integration of extensible multiple functions; and a 'soft-path' that will complement the former by improving the functions to satisfy the demand more efficiently. While the traditional hard-path approach has produced, and will continue to produce, enormous benefits, there is a need to develop soft-path solutions to meet the demand more precisely and efficiently rather than providing overmuch supply. The Google company has began to analyze the habit of their customers based on the big data obtained from free use of the Google software products to provide advertisement more accurately to targeted customers. In the future, when it is possible to establish the data base of the personal health information and the doctor experience information, it may be possible to find the most appropriate doctor for each individual patient very quickly based on intelligent big data technology. Another example could be found in intelligent central-air-conditioner. This type of air conditioner could collect and analyze the user's individual preferred temperature and automatic adjust the temperature when different persons coming in the room. If there are multiple persons here, it can find a most suitable temperature by using group preference analysis technology.

As a result, the soft-path needs to establish an intelligent system which has the ability of intelligent data acquisition, data identification, data analysis, and make decisions automatically and intelligently based on integrated big data processing technologies, decision making modeling methods, and intelligent algorithms as well as considering the human involvement, societal characteristics, dynamic characteristics, and uncertainty. This research would like to build a methodology of metasynthesis-based intelligent big data processing paradigm which works based on the mechanisms of metasynthesis-architecture (i.e., M-architecture) and metasynthesis-technology (i.e., M-technology), and the principle of metasynthesis-intelligence (i.e., M-intelligence) for achieving the ability of integrated intelligent big data processing.

39.2 Literature Review

There have been many studies on the intelligent big data processing. With the increasing convergence among grid and cloud computing and big data intelligence, different approaches have been developed, challenges and opportunities are still numerous in this research field. The current research progresses in the field are focusing on big data architectures, big data processing systems, big data management, and big data applications and modeling, MapReduce optimization, resources allocation, resource monitoring, energy-aware resource provisioning. All of these studies not only provide novel ideas and state-of-the-art techniques in the field, but also stimulate future research in the sustainable environment.

39.2.1 Big Data Architectures

With the ubiquity of many-core architectures in recent years and foreseeable future, the many-core platform will be one of the main computing platforms to execute MapReduce programs. Lin and Chung [13] explored the shared memory programming schemes for masterworker MapReduce processing on the TILE64 many-core platform. The authors model and compare two shared memory implementation schemes, master share and worker share. Theoretical analysis shows that the worker share scheme is inherently better for the implementation of MapReduce library on the TILE64 many-core platform. Pungila et al. [19] presented an innovative, massively parallel heterogeneous architecture for the very fast construction and implementation of very large Aho-Corasick and Commentz-Walter pattern-matching automata, commonly used in data-matching applications, and validates its use with large sets of data actively used in intrusion detection systems. The proposed approach represents the first known hybrid-parallel model for the construction of such automata and the first to allow self adjusting pattern-matching automata in real-time by allowing full-duplex transfers at maximum throughput between the host (CPU) and the device (GPU).

39.2.2 Big Data Processing Systems

Knowledge processing has found its successful applications in a very wide range: social network analysis, expert system, data mining, business process management, search engine, etc. Liu and von Wichert [14] proposed a generalizable knowledge framework for data abstraction, i.e. finding a compact abstract model for input data using predefined abstract terms. Based on these abstract terms,intelligent autonomous systems, such as a robot, should be able to make inference according to the specific knowledge base, so that they can better handle the complexity and uncertainty of the real world. The authors show in detail how to adapt this framework to a certain task, in particular, semantic robot mapping. Chau et al. [4] introduced a novel method for SVM classification. A decision tree is used to detect low entropy regions in input space, and Fisher's linear discriminant is applied to detect the data near to support vectors. Experimental results demonstrate that the proposed approach has good classification accuracy and low standard deviation; the training is significantly faster than the other existing methods.

39.2.3 Big Data Management

The ability of processing and analyzing big data plays a key role in most modern enterprises today. So, the technology of MapReduce which has the ability to automatically parallelize the application on a cluster of commodity hardware and can efficiently and quickly process terabytes and petabytes of data becomes popular to all sizes of enterprises. Lu et al. [15] presented Morpho-a modified version of the Hadoop MapReduce framework, which decouples storage and computation into physic clusters and virtual clusters respectively. The proposed data location perception module can enhance the cooperation between computation and storage layer. The energy efficiency of servers plays a significant role in the overall energy consumption of a data center. Wang et al. [24] focused on how to improve servers' energy efficiency by appropriate data placement policies and task scheduling schemes. This work proposed a new multiobjective bi-level programming model based on MapReduce. In the proposed model, not only is the relationship between performance and energy consumption taken into consideration, but also task data locality can be adjusted according to the current network state.

39.2.4 Big Data Application

As the real-time requirement of data dissemination becomes increasingly significant in many fields, the emergency applications have received increasing attention. The publish/subscribe (pub/sub) paradigm is a key technology for asynchronous data dissemination that is widely used in the emergency applications. It decouples senders and receivers of the emergency applications in space, time, and synchronization, which enable a pub/subsystem to seamlessly expand to massive size. Ma et al. [16] proposed SEMAS, a scalable and elastic event matching service for attribute-based pub/subsystems in the cloud computing environment. A prototype system on an

OpenStack-based platform demonstrates that SEMAS has a linear increasing matching capacity as the number of servers and the partitioning granularity increase.

39.3 Problem Statement

Not a moment too soon, the world is awakening to the need to rethink fundamentally the way to acquire, identify, and analyze the big data resources for discovering valuable information to help improve quality of life and make our world a better place.

Recently, several US government agencies, such as the National Institutes of Health (NIH) and the National Science Foundation (NSF) of U.S., ascertain that the utilities of big data to data-intensive decision-making have profound influences in their future developments. Consequently, they are trying to developing Big Data technologies and techniques to facilitate their missions after US government passed a large-scale big data initiative. This initiative is very helpful for building new capabilities for exploiting informative knowledge and facilitate decision-makers. From the Networking Information Technology Research and Development (NITRD) program which is recently recognized by the U.S. President's Council of Advisors on Science and Technology (PCAST), it could be known that the bridges between Big Data and knowledge hidden in it are highly crucial in all areas of national priority. This initiative will also lay the groundwork for complementary Big Data activities, such as Big Data infrastructure projects, platforms development, and techniques in settling complex, data-driven problems in sciences and engineering. Finally, they will be put into practice and benefit society.

According to the report from McKinsey institute [17], the effective use of Big Data has the underlying benefits to transform economies, and delivering a new wave of productive growth. Taking advantages of valuable knowledge beyond Big Data will become the basic competition for today's enterprises and will create new competitors who are able to attract employees that have the critical skills on Big Data. Researchers, policy and decision makers have to recognize the potential of harnessing Big Data to uncover the next wave of growth in their fields. There are many advantages in business section that can be obtained through harnessing Big Data, including increasing operational efficiency, informing strategic direction, developing better customer service, identifying and developing new products and services, identifying new customers and markets, etc. The vertical axis denotes the percentages that how many enterprises think Big Data can help them with respect to specific purposes. By liberal estimates [17], big data could produce $300 billion potential annual value to US health care, and $250 billion to European public administration. There will be $600 billion potential annual consumer surplus from using personal location data globally, and give a potential increase with 60 %. Only in the United States, Big Data produce 140,000–190,000 deep analytical talent positions and 1.5 million data-savvy managers [5]. Undoubtedly, big data is usually juicy and lucrative if explored correctly. The importance of this research is that the proposed work will find a way to realize integrated intelligent big data processing that can meet the people's demand more efficiently and with better effectiveness. This could bring significant benefit for the society as well as enrich the knowledge of big data management and applications.

39.4 Methodology Framework of Metasynthesis

The proposed work of this research are based on the academic thoughts of metasynthesis which is a methodology that is suitable to deal with open complex giant systems such as big data systems. The metasynthesis, first proposed by Qian et al. [20–22] in 1990s, is the contraction of Qualitative-to-Quantitative Metasynthesis, which is the methodology proposed for studying open complex giant systems. It combines qualitative research with quantitative research, and utilize the idea of systematic thought to combine a variety of disciplines for comprehensive research. It also synthesizes the macro and micro research based on the hierarchical structure of complex giant system. The methodology highlights the crucially on-demand involvements and seamless synergy of the relevant expert group, data, information, knowledge, computer systems, as well as scientific theory of various disciplines and human experience and knowledge. This makes a system in itself. The methodology is originally called a Metasynthesis Engineering method from the technical perspective. Due to the involvement and significant role of social intelligence in the problem-solving of open complex giant systems, it is a kind of Metasynthetic Social Intelligence Engineering. The academic thoughts of artificial intelligent, system engineering theory, dynamic programming, and decision making theory could also support to the proposed work of this research.

To understand the methodology framework of metasynthesis for intelligent big data processing, the theoretical foundation of DIKW (Data-Information-Knowledge-Wisdom) Pyramid [27], proposed by Zeleny in 1987, should be first introduced. DIKW is data, information, knowledge, wisdom: a four layer hierarchy, where each layer adds certain attributes over and above the previous one. Data is the most basic level; Information adds context; Knowledge adds how to use it; Wisdom adds when and why to use it. DIKW is a hierarchy useful to understanding analysis and the importance and limits of conceptual works. Zeleny builds the DIKW hierarchy by equating data, information, knowledge, and wisdom to "know-nothing", "know-what", "know-how", and "know-why" respectively. Ackoff [1] added the "understanding" between knowledge and wisdom. The methodology of metasynthesis for intelligent big data processing actually plays a role of letting people know what to do and how to do. Figure 39.1 shows the relationship between the methodology of metasynthesis and intelligent big data processing.

The methodology of metasynthesis is suitable for dealing with open complex giant systems. In fact, the big data system is actually an open complex giant system consisting of the following features.

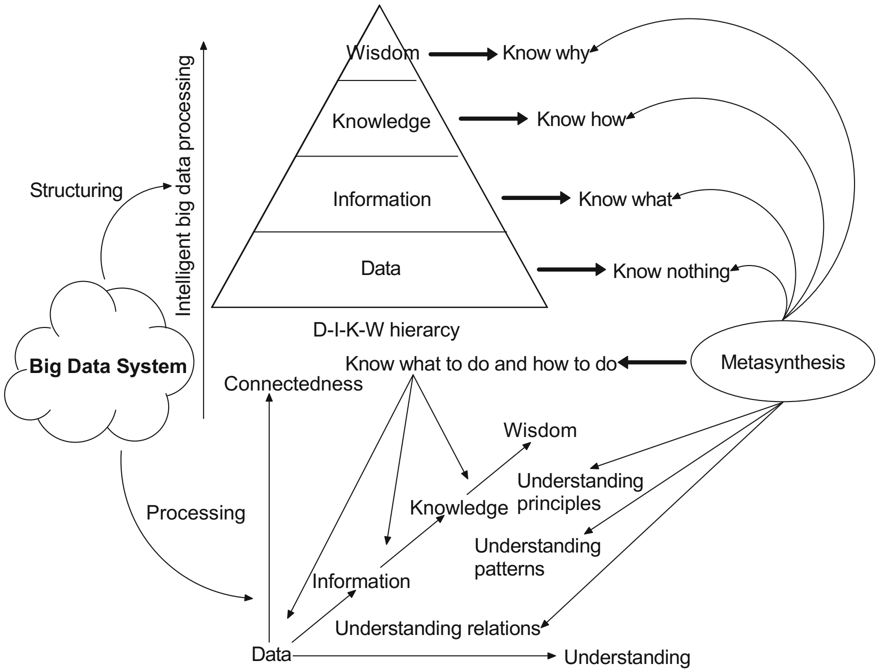


Fig. 39.1 Relationship between the methodology of metasynthesis and intelligent big data processing

(1) Openness: A big data system exchanges information, energy and materials with its external environment.
(2) Giant scale: A big data system is composed of hundreds or even millions of system constituents and components.
(3) Hierarchy: There are usually many levels in a big data system. In some cases, the number of levels is unknown. It may consist of many sub-systems, which may further include sub-sub-systems.
(4) Human involvement: Relevant human beings are an essential constituent of a big data system.
(5) Societal characteristics: Many social factors such as laws, politics, organizational factors, and business processes are embedded in a big data system.
(6) Dynamic characteristics: A big data system is dynamic in the sense that it may change its states, working mechanism, constituents, and internal and external interaction mechanisms at any time often beyond one's imagination.
(7) Uncertainty: At any time point, the system state of a big data system may not be quite clear; in many cases, our understanding of such a system is uncertain, meaning that we do not have a solid and recognizable conclusion about the underlying problem.

(8) Imprecision: Our understanding of the system is imprecise at a certain stage; such imprecise understanding may continue for quite a long time before a precise one can be obtained.

In order to deal with the complexity of big data system and establish an intelligent big data processing problem-solving methodology, an idea of "3M" structure of metasynthesis is proposed in this research. Figure 39.2 shows their structure. The three key components, M-architecture, M-technology, and M-intelligence, consist of a systematic framework for instantiating the theory of metasynthesis in handling the problem solving of intelligent big data processing. The mechanism of M-architecture is to build a system structure from an unstructured or ill-structured big data system. Here the system structure for M-architecture is not just a data structure, but an integration of data structure, domain structure, technology structure, social structure, and environmental structure. The mechanism of M-technology is to provide techniques and technologies support for the problem solving of intelligent big data processing. The M-technology is an integration of analysis technology, design technology, modeling technology, simulating technology, optimization technology. The mechanisms of M-architecture and M-technology are not independent, but will interact with each other. The working principle of the interactions between M-architecture and M-technology is M-intelligence which is the integration of data intelligence, human intelligence, domain intelligence, social intelligence, and network intelligence.

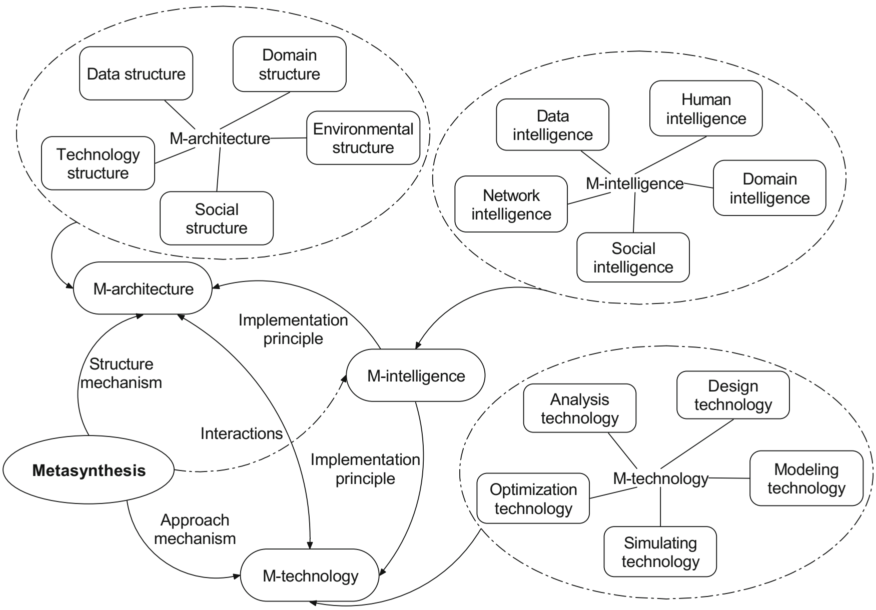


Fig. 39.2 "3M" structure of metasynthesis for problem solving of intelligent big data processing

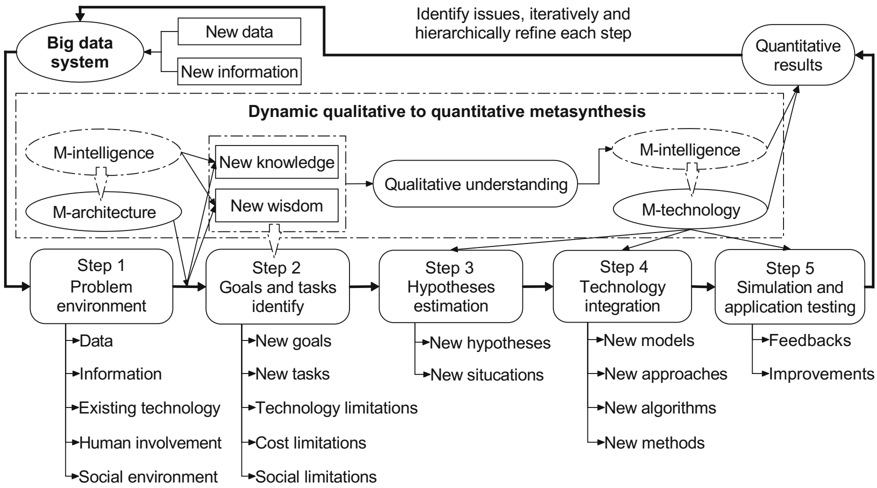


Fig. 39.3 Big data system problem-solving methodology framework: Metasynthesis-based intelligent big data processing paradigm

The "3M", i.e., M-architecture, M-technology, and M-intelligence, form the methodology of metasynthesis for big data system problem-solving. The principle idea of "3M" metasynthesis for big data system problem-solving which is named metasynthesis-based intelligent big data processing paradigm is shown in Fig. 39.3. Due to the constant growth of big data system with new data and new information, the principle idea of chemosynthesis intelligent big data processing paradigm is actually a dynamic qualitative to quantitative metasynthesis methodology. Based on the mechanism of M-architecture which follows the principle of M-intelligence, the new goals and tasks can be identified under the guidance of extracted new knowledge and new wisdom according to the problem environment involving data, information, existing technology, human involvement, and social environment. This qualitative understanding is the starting state of our cognition of the problem. Following the mechanism of M-technology and the principle of M-intelligence, technology integration with new models, new approaches, new algorithms, and new methods can be implemented based on new hypotheses and new situations. Then simulation and application testing can be made to obtain feedbacks and make improvements of the integrated intelligent big data processing technologies. The obtained quantitative results are not the final results, but will be used and examined in the dynamic growing big data system to identify new issues, iteratively and hierarchically refine the above each step. During each iteration, the interaction among M-architecture, M-technology, and M-intelligence may trigger new understanding and possibly creative cognition of the underlying problem. For each such iteration, there may emerge new objectives, approaches and methods, data and resources, as well as the progress of periodically consequent models, methods, and knowledge about the system and problem solving. Therefore, the understanding of a big data system is an intelligence emergence in a qualitative-to-quantitative process based on social cognitive interaction.

39.5 Application Prospects

In the 21st century, two paths lie before human in the big data era: a 'hard path' that will rely almost exclusively on the development of computer and internet technologies (hardware and software) to achieve the integration of extensible multiple functions, such as iPhone, iWatch, smart home, business intelligence system; and a 'soft-path' that will complement the former by improving the functions to satisfy the demand more efficiently and with better effectiveness.

The applications of intelligent big data processing may involve multiple fields, including commerce and business, society administration, construction planning and management, hospital operation scheduling, transportation network system, traffic intelligent control system, Chinese-character recognition, intelligent building systems, agile supply-chain management, regional sustainability, population, analyzing and evaluating public opinion on the Internet, resources and environmental economics, and digital urban planning. Multidisciplinary methods are needed to discovery the valuable information from big data and making decisions intelligently.

39.6 Conclusion

This research focuses on the 'soft-path' to promote the development of a methodology of metasynthesis-based intelligent big data processing paradigm. Here the "metasynthesis" is the contraction of Qualitative-to-Quantitative Metasynthesis, which is the methodology proposed for studying open complex giant system problems. The present state of knowledge in the fields of big data architectures, big data processing systems, big data management, and big data applications and modeling, MapReduce optimization, resources allocation, resource monitoring, energy-aware resource provisioning, transportation network system, traffic control system, water resource planning and management, and so on, actually provide sufficient foundations of theories, methodologies, and technologies for the proposed work. This research not only integrates the current theories, methodologies, and technologies in the fields, but also develop new theories, methodologies, and technologies to form a theoretical system of metasynthesis-based intelligent big data processing paradigm along with the idea of "soft-path" development.

The proposed activity of this research can significantly advance the knowledge of big data processing technologies, reveal the internal laws and principles of the "soft-path" for big data era, promote the creation, development, and application of the next generation of mathematical, computational and statistical theories and tools that are essential for addressing the challenges of intelligent big data processing, and develop the mechanisms of M-architecture and M-technology and the principle of M-intelligence which are the core of the methodology of metasynthesis for big data processing.

The proposed activity can achieve benefit through two levels of impacts. The first level of impact is from the idea of "soft-path". If the research to develop the above methodology could be successfully achieved, it will open a new trend to motivate the intelligentializing of big data processing for improving the functions to satisfy the demand of humans more efficiently in multiple fields including, intelligent hospital, smart internet search engine, water resource management, electronic commerce intelligent system, and so on. The second level of impact can bring significant big data processing technologies improvements and achieve novel applications of metasynthesis-based intelligent big data processing systems to help improve quality of life and make our world a better place.

Acknowledgments This research was supported by the the Youth Program of National Natural Science Foundation of China (Grant No. 71501137), the General Programs of China Postdoctoral Science Foundation (Grant No. 2015M572470; Grant No. 2015M572480), the International Postdoctoral Exchange Fellowship Program of China Postdoctoral Council (Grant No. 20150028), and also funded by Sichuan University (Grant No. skzx2015-sb04; Grant No. skqy201647). The authors would like to give our great appreciation to the editors and anonymous referees for their helpful and constructive comments and suggestions, which have helped to improve this article.

References

1. Ackoff R (2010) From data to wisdom. J Appl Syst Anal 16:3–9
2. Barbierato E, Gribaudo M, Iacono M (2014) Performance evaluation of NoSQL big-data applications using multi-formalism models. Future Gener Comput Syst 37:345–353
3. Castiglione A, Gribaudo M et al (2014) Exploiting mean field analysis to model performances of big data architectures. Future Gener Comput Syst 37:203–211
4. Chau A, Li X, Yu W (2014) Support vector machine classification for large datasets using decision tree and Fisher linear discriminant. Future Gener Comput Syst 36:57–65
5. Chen C, Zhang C (2014) Data-intensive applications, challenges, techniques and technologies: a survey on big data. Inf Sci 275:314–347
6. Chen J, Chen Y et al (2013) Big data challenge: a data management perspective. Front Comput Sci 7(2):157–164
7. Dobre C, Xhafa F (2014) Intelligent services for big data science. Future Gener Comput Syst 37:267–281
8. Fiore U, Palmieri F et al (2014) A cluster-based data-centric model for network-aware task scheduling in distributed systems. Int J Parallel Program 42(5):755–775
9. George G, Haas M, Pentland A (2014) Big data and management. Acad Manag J 57(2):321–326
10. Ku M, Choi E, Min D (2014) An analysis of performance factors on Esper-based stream big data processing in a virtualized environment. Int J Commun Syst 27(6):898–917
11. Kwon O, Lee N, Shin B (2014) Data quality management, data usage experience and acquisition intention of big data analytics. Int J Inf Manag 34(3):387–394
12. Lee D, Kim J, Maeng S (2014) Large-scale incremental processing with MapReduce. Future Gener Comput Syst 36:66–79

13. Lin X, Chung Y (2014) Master-worker model for MapReduce paradigm on the TILE64 many-core platform. Future Gener Comput Syst 36:19–30
14. Liu Z, von Wichert G (2014) A generalizable knowledge framework for semantic indoor mapping based on Markov logic networks and data driven MCMC. Future Gener Comput Syst 36:42–56
15. Lu L, Shi X et al (2014) Morpho: a decoupled MapReduce framework for elastic cloud computing. Future Gener Comput Syst 36:80–90
16. Ma X, Wang Y et al (2014) Scalable and elastic event matching for attribute-based publish/subscribe systems. Future Gener Comput Syst 36:102–119
17. Manyika J, Chui M et al (2012) Big data: the next frontier for innovation, competition, and productivity. Mckinsey Global Institute
18. Park J, Kim H et al (2014) Two-phase grouping-based resource management for big data processing in mobile cloud computing. Int J Commun Syst 27(6):839–851
19. Pungila C, Reja M, Negru V (2014) Efficient parallel automata construction for hybrid resource-impelled data-matching. Future Gener Comput Syst 36:31–41
20. Qian X, Tsien H (1991) Revisiting issues on open complex giant systems. Pattern Recognit Artif Intell 4(1):5–8
21. Qian X, Yu J, Dai Y (1990) A new scientific field-open complex giant systems and the methodology. Chin J Nat 13(1):3–10
22. Qian X, Yu J, Dai Y (1993) A new discipline of science-the study of open complex giant system and its methodology. J Syst Eng Electron 4(2):2–12
23. Singh K, Guntuku S et al (2014) Big data analytics framework for peer-to-peer botnet detection using random forests. Inf Sci 278:488–497
24. Wang X, Wang Y, Cui Y (2014) A new multi-objective bi-level programming model for energy and locality aware multi-job scheduling in cloud computing. Future Gener Comput Syst 36:91–101
25. Xhafa F, Barolli L (2014) Semantics, intelligent processing and services for big data. Future Gener Comput Syst 37:201–202
26. Yoo C, Ramirez L, Liuzzi J (2014) Big data analysis using modern statistical and machine learning methods in medicine. Int Neurourol J 18(2):50–57
27. Zeleny M (1987) Management support systems: towards integrated knowledge management. Hum Syst Manag 7(1):59–70
28. Zhao J, Wang L et al (2014) A security framework in G-Hadoop for big data computing across distributed cloud data centres. J Comput Syst Sci 80(5):994–1007

Chapter 40
The Structure and Mechanism of Voice Behavior: Based on the Perspective of Motivation

Hao Zhou, Lei Feng and Anni Liu

Abstract Employees' new ideas are of most value for the innovation of organization, and the new ideas are often rooted in voice behavior. Due to the different values and psychological needs, there are differences in employee voice behavior motivation. Based on the perspective of motivation, we proposed a three-dimensional model of voice behavior: self-interested voice, win-win voice, and altruistic voice. Moreover, we discussed the mechanism of the voice intention and voice implementation. Finally, future research directions were proposed.

Keywords Voice behavior · Motivation · Job satisfaction · Managerial openness

40.1 Introduction

With the increasingly fierce competition, more and more organizations strive to obtain sustained competitiveness through innovation [4, 11]. Employees' voice behavior, acting as an important source of organizational innovation, becomes the focus of management practitioners and researchers [17, 25].

The study of voice behavior starts from Hirschman, he believes that employees with low job satisfaction express dissatisfaction with the two reactions: First, voice, and second, changing the position or turnover. The latter is destructive, belonging to negative reactions. Therefore, high loyal employees are more inclined to express their dissatisfaction actively. Based on this idea, Hirschman [10] built the EVLN model (exit, voice, loyalty and neglect) to capture employees' response to job satisfaction. That model formally proposed the concept of voice behavior and argued that voice behavior was a positive and constructive behavior caused by dissatisfaction with the organization. Subsequently, Dyne et al. [9] defined voice behavior as an expression of behavior expressed by employees, which aimed at improvement but was not a part of the job requirement. Thus voice behavior is an innovation-oriented extra-role

H. Zhou (✉) · L. Feng · A. Liu
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: zhouhao@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_40

behavior. It means that the purpose of voice behavior is to make the improvement, rather than simply criticism [18, 22]. Besides, voice behavior is also different from complaint and whistle-blowing and helping. The complaint is only an outlet, it cannot provide constructive suggestions for the organization, and cannot improve organizational effectiveness. Whistle-Blowing refers to the exposing of unethical behavior within the organization [28]. Helping is a kind of prosocial behavior to maintain the harmony. While voice behavior is a change-oriented challenging behavior, which would easily lead to interpersonal conflicts and destroy the harmony of the organization. Therefore, helping and voice behavior construct two extremes of the civic virtue [14].

Both of the constructiveness and initiatives of voice behavior have positive impacts on employees and organizations [15]. Avey et al. [2] found that ethical leadership had a positive influence on employees' psychological well-being by encouraging employees' voice behavior. Gino and Schweitzer [12] found that voice contributed to management efficiency. Liang and Tang's multilevel analysis [19] found that employees' voice behavior had positive impacts on both individual innovation performance and organizational performance.

As the underlying causes of triggering the behavior, motivation is a critical factor that affects employees' behavior. However, the existing research paid little attention to the relationship between motivation and voice behavior. Therefore, in the present study, based on the perspective of motivation, we construct a new three-dimensional model of voice behavior, and to explore the intrinsic mechanism of voice behavior.

40.2 Literature Review

With the insight into this field, researchers have increasingly expanded the construct of voice behavior. Based on the perspective of conflict management, Hagedoorn et al. [15] divided voice into considerate voice and aggressive voice. They proposed that considerate voice was a positive, constructive form of voice, which was actualized by employees' need to solve the problems concerned with themselves and organizations. Contrarily, the aggressive voice was a negative, destructive form of voice, which was driven by employees' concern on their benefits. Based on the perspective of different targets of voice, Liu et al. [23] divided voice into speaking up (supervisor as the target) and speaking out (colleagues as the target). At present, the researchers generally accept Liang and Farh's two-dimensional model: promotive voice and prohibitive voice [20]. Promotive voice refers to the innovative ideas expressed by employees to improve the efficiency of the organization. While prohibitive voice refers to preventive ideas proposed by employees to solve the problems that hinder the operation of the organization.

Motivation is the internal factor that motivates and maintains people's actions, make action oriented to a target, and meet the needs of the individual. Duan and Zhang [7] pointed out that as a kind of self-initiated, schema-activated or scripts-affected initiative behavior, voice behavior was generated by the motivation. Currently, there are two models based on the perspective of motivation to study voice behavior. The first one is the three-dimensional voice structure proposed by Van Dyne et al. the second is two-dimensional voice structure proposed by Duan and Ling.

According to the differences of the motivations, Dyne et al. [9] divided voice behavior into acquiescent voice, defensive voice and prosocial voice. The motivation of acquiescent voice derives from individual's self-efficacy. When the self-efficacy is low, employees will hide their thoughts and agree or acquiesce the views of others. The motivation of defensive voice comes from individual's fear. When employees have a feeling of fear, they usually express the information and ideas related to the job for the purpose of self-protection. The motivation of prosocial voice comes from individual's cooperation, close cooperation promotes employees, based on altruistic orientation, to propose problems related to their jobs or openly express their views.

Motivation comes from need. Duan and Ling [6], based on the different psychological needs of employees, divided voice behavior into overall-oriented voice and self-centered voice within the Chinese context. Overall-oriented voice reflects the need for integration with the context, with the characteristics of serially analytical processing and low social risks. Self-centered voice reflects the need for self-enhancement, with the features of heuristic processing and high social risks. The first difference between Duan's model and Hagedoorn's two-dimensional model lies in the cultural values. Dividing voice behavior into considerate voice and aggressive voice reflects the values of individualism. While dividing voice behavior into overall-oriented voice and self-centered voice reflects the values of collectivism. Besides, the theoretical basis of the two models is different. The research of Hagedoorn, based on the EVLN framework, emphasizes that voice behavior is a response to employees' dissatisfaction with the status quo. The source of Duan and Ling's study is the opinion proposed by Van Dyne and Lepine that voice behavior is a contributive behavior, characterized by "altruistic" or "organization-benefit" [28]. According to the existing literature, the discussion of motivation is critical to understand voice behavior. However, previous studies did not reach an agreement on this issue. Therefore, there is still a large space to explore.

40.3 Structure of Voice Behavior: Three Dimensions

The voice behavior reflects individual's psychological needs [13]. Based on organismic theory, Duan and Ling proposed that voice behavior originated from two kinds of opposite psychological needs: the need for the integration of the context and the need for independent enhancement [6]. These two fundamental psychological needs lead to the O motivation (union with others) and the S motivation (self-enhancement) respectively. The present study also starts from the psychological needs of employees, further expands the organismic theory, and divides the original O motivation and S motivation into three categories: Self-enhancement motivation, organizational harmony motivation, and relationship-enhancement motivation. Further, we propose a new voice structure to match it.

Self-enhancement motivation reflects the degree of individual's concern of their self-interest. The stronger the self-enhancement motivation is, the higher employees' concern for their interests. Driven by Self-enhancement motivation, employees pay more attention to individual's progress and development, which makes them have no more energy to consider the interests of others or organizations, in turn, which can easily lead to conflicts within groups or organizations. Therefore, the voice behavior driven by self-enhancement motivation often benefits individuals who speak out. In the current study, we define this kind of voice as self-interested voice.

The organizational harmony motivation is the coordination and balance between the interests of individuals and the organizations. High organizational harmony motivation implies that the interests of individuals and organizations are consistent. On the contrary, low organizational harmony motivation implies that the relationship between the interests of individuals and organizations is weak, and even conflicted. To avoid conflicts, employees who pay close attention to organizational harmony are more likely to develop with organizations. Therefore, the voice behavior driven by the organizational harmony motivation is always in the pursuit of a win-win result. In the current study, we define this type of voice as win-win voice.

Different with the self-enhancement motivation, the relationship-enhancement motivation shows the willingness of employees to maintain and strengthen the social exchange relationship with the organization. When employees perceive the fairness and trust in the organization, they will generate the motivation to benefit the organization based on the norm of reciprocity. This motivation will stimulate them to perform the extra-role prosocial behavior, including voice behavior. In the present study, we define this type of voice as altruistic voice.

Self-interested voice, win-win voice, and altruistic voice constitute the three-dimensional model of voice based on motivation. It is important to note that, on the one hand, these three kinds of voice behaviors driven by three different motivations, therefore there are apparent differences between each other. On the other hand, just as a person can have a variety of needs, the needs in different situations will change too, and the motivation will also change accordingly. Therefore, employees may exhibit a variety of voice behaviors, and what kind of voice behavior will be presented mainly depends on what kind of motivation is strongest.

40.4 Mechanism of Voice Behavior: Two-Stage Model

The second aim of this study is to analyze the mechanism of the three-dimensional voice behavior. According to the theory of planned behavior (TPB), the generation of behaviors includes two stages: behavior intention and behavior implementation [1]. Based on TPB, the present study divides the process of voice into two phases: voice intention and speaking out. Voice intention is the result of job satisfaction and self-expectation, whereas speaking out is the interactive effect of voice intention and managerial openness.

40.4.1 The First Stage: Job Satisfaction, Self-Expectation, and Voice Intention

Job satisfaction is the degree of how employees satisfy with their jobs, which is regarded as one of the important factors that affect voice behavior. Hagedoorn et al. [15] analyzed job satisfaction in five aspects: job itself, regulations, payment, promotion and colleagues, and for the first time confirmed the positive relationship between job satisfaction and voice behavior. Since then, there are two opposite perspectives on the issue of the influence of job satisfaction on voice behavior. Some scholars think that employees speak out only in low job satisfaction [10, 27], and the purpose of voice is to express their discontent. While other scholars believe that employees speak out only in high job satisfaction, just as Liu et al. [23] found that "I warn you because I like you". Thus, the relationship between job satisfaction and voice behavior is complicated, and may even be nonlinear. Duan and Zhong [8] proposed that there was a U-shaped relationship between the job satisfaction and voice behavior. Although the hypothesis was not supported, the idea provided a new perspective to explore the relationship between job satisfaction and voice behavior.

According to TPB, job satisfaction should have the direct effect on voice intention. Behavior intention refers to the subjective judgment of the probability to take a particular action [1]. Compared with behavior, intention reflects the individual's cognitive status. In other words, the perception will affect the intention firstly, and then acts on the behavior through the intention. Thus, we predict that job satisfaction will have a direct impact on the employees' voice intention.

As mentioned above, the aim of self-interested voice focuses on the benefits of employees. When job satisfaction is low, it means that individual's benefits are not met. To compensate for themselves, employees will generate a self-interested voice intention. Conversely, when the job satisfaction is high, which means personal interests get effective protection, and employees' self-enhancement motivation are satisfied, so, the self-interested voice intention will be reduced. In a word, job satisfaction may have a negative effect on self-interested voice intention.

Altruistic voice emphasizes the norm of reciprocity in the social exchange relationship. When employees perceive high job satisfaction, it means that they are trusted and respected in the organization. To maintain and strengthen the social exchange relationship with the organization, employees generate a high altruistic voice intention. Accordingly, when employees perceive low job satisfaction, they will generate a low altruistic voice intention. In a word, job satisfaction may have a positive impact on altruistic voice intention.

Win-win voice concerns the organizational harmony. Whether job satisfaction is high or low, either organization's or employees' benefit are satisfied. It is difficult for employees to coordinate the relationship between individuals and organization, and thus employees will generate a low win-win voice intention. Instead, when job satisfaction is on the middle level, employees not only have the motivation to protect their interests, but also have the intention to maintain organization's benefit. Therefore, employees will generate a win-win voice intention to maintain a stable relationship

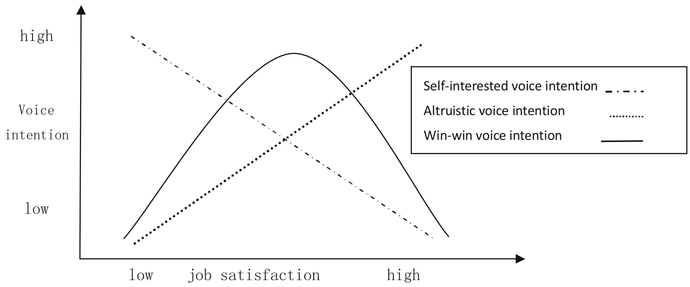


Fig. 40.1 The relationship between job satisfaction and voice intention

with the organization. In a word, there may be an inverted U-shape relationship between job satisfaction and win-win voice intention, as shown in Fig. 40.1.

40.4.2 The Second Stage: Voice Intention, Managerial Openness and Voice Behavior

According to TPB, individual's evaluation of the results of behavior is a major factor to affect the relationship between intention and behavior. If individuals anticipate that taking actions will bring positive results, they will be more willing to engage in that behavior. Conversely, they will inhibit their actions [1].

The research of managerial openness started from House and Rizzo, who proposed the concept of top management receptiveness, and argued that when managers had an open mind, subordinates dared to speak out. On the contrary, if the manager was narrow-minded, subordinates usually disagreed with the manager [16]. Managerial openness, acting as a change-oriented leadership style, means that subordinates perceive that their managers are willing to listen to their ideas, are interested in their thoughts, would like to think about their views, and sometimes even take their ideas into action [5]. In other words, high managerial openness implies that employees do not need to worry about interpersonal risks and punishments, when they offer advice to their leaders. Therefore, high managerial openness leads to positive expectation and encourages employees to implement voice behavior. The study of Deter found the positive relationship between managerial openness and voice behavior [5].

In addition to the direct effect on voice behavior, managerial openness would moderate the relationship between voice intention and voice behavior. Ling et al. [21] found that managerial openness produced a strong situation, which could weaken the negative relationship between shyness and voice behavior. While the study of Sun [26] showed that managerial openness would weaken the influence of core self-evaluation on voice behavior. High managerial openness provides a favorable external environment for employees' voice behavior. It not only eliminates employees' worries about the negative outcomes of voice behavior, but also implies greater

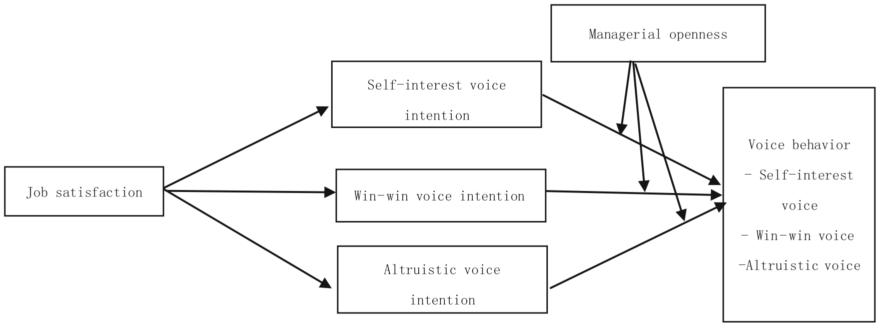


Fig. 40.2 Two-stage model of voice behavior

autonomy, which can motivate employees to transform voice intention into voice behavior. Conversely, low managerial openness will lead to the negative expectation and threat employees' psychological safety, thereby reduces the possibility of employees to express their ideas. Based on the analysis above, we propose that managerial openness moderates the relationship between voice intention and voice behavior, as shown in Fig. 40.2.

40.5 Conclusion and Future Directions

In the context of innovation-driven development, how to stimulate the voice behavior has become a common problem for both scholars and managers [24]. This study analyzed and evaluated the concept, function, and types of voice behavior through the literature review, and discussed the structure and mechanism of voice behavior from the perspective of motivation. Based on previous studies, we constructed a three-dimensional voice model. Besides, we also constructed a two-stage model of voice behavior based on the Theory of Planning Behavior.

For future study, first, the three-dimensional voice model needs to be examined in future empirical research. Second, previous studies have found that zhongyong, guanxi, mianzi, and renqing could influence voice behavior within Chinese cultural background [3]. Future research can integrate these indigenous variables into the voice model. Finally, based on the three-dimensional model proposed by this study, future research can explore how to motivate employees' altruistic voice and win-win voice, and to inhibit employee's self-interested voice. By promoting the ability of continual improvement and innovation, voice behavior ultimately improves the organizational competitiveness.

Acknowledgments This research was supported by the National Natural Science Foundation of China (71472129), and Sichuan Research Center of System Science and Corporate Development (xq15B04).

References

1. Ajzen I (1991) The theory of planned behavior. Organ Behav Hum Decis Process 50(2):179–211
2. Avey JB, Wernsing TS, Palanski ME (2012) Exploring the process of ethical leadership: the mediating role of employee voice and psychological ownership. J Bus Eth 107(1):21–34
3. Chen WP, Duan JY (2013) Why do not employees voice: a Chinese culture perspective. Adv Psychol Sci 21:905–913 (In Chinese)
4. Chen ASY, Hou YH (2016) The effects of ethical leadership, voice behavior and climates for innovation on creativity: a moderated mediation examination. Leadersh Q 27(1):1–13
5. Detert JR, Burris ER (2007) Leadership behavior and employee voice: is the door really open? Acad Manag J 50(4):869–884
6. Duan JY, Lin B (2012) A Chinese indigenous study of the construct of employee voice behavior and the influence of Zhongyong on it. Acta Psychol Sin 43:1185–1197 (in Chinese)
7. Duan JY, Zhang Q (2012) The study of voice behavior in the perspective of cognition: cognitive factors, theoretical basis and formation mechanism. Adv Psychol Sci 20:115–126 (in Chinese)
8. Duan JY, Zhong JN (2012) Investigating the relationship between job satisfaction and voice behavior moderated by organizational commitment. J Ind Eng Eng Manag 26:170–174 (in Chinese)
9. Dyne LV, Ang S, Botero IC (2003) Conceptualizing employee silence and employee voice as multidimensional constructs*. J Manag Stud 40(6):1359–1392
10. Exit AOH (1970) Voice, and loyalty: responses to decline in firms. Organizations, and states. Harvard University Press, Cambridge
11. Frieder RE, Hochwarter WA, DeOrtentiis PS (2015) Attenuating the negative effects of abusive supervision: the role of proactive voice behavior and resource management ability. Leadersh Q 26(5):821–837
12. Gino F, Schweitzer ME (2008) Blinded by anger or feeling the love: how emotions influence advice taking. J Appl Psychol 93(5):1165
13. Gorden WI (1988) Range of employee voice. Empl Responsib Rights J 1(4):283–299
14. Graham JW, Van Dyne L (2006) Gathering information and exercising influence: two forms of civic virtue organizational citizenship behavior. Empl Responsib Rights J 18(2):89–109
15. Hagedoorn M, Van Yperen NW, Van de Vliert E, Buunk BP (1999) Employees' reactions to problematic events: a circumplex structure of five categories of responses, and the role of job satisfaction. J Organ Behav 20(3):309–321
16. House RJ, Rizzo JR (1972) Toward the measurement of organizational practices: scale development and validation. J Appl Psychol 56(5):388
17. Janssen O, Gao L (2013) Supervisory responsiveness and employee self-perceived status and voice behavior. J Manag 1:1–19
18. Li Y, Sun JM (2015) Traditional chinese leadership and employee voice behavior: a cross-level examination. Leadersh Q 26(2):172–189
19. Liang J, Tang J (2009) A multi-level study of employee voice: evidence from a chain of retail stores in China. Nankai Bus Rev 13:125–134 (in Chinese)
20. Liang J, Farh CI, Farh JL (2012) Psychological antecedents of promotive and prohibitive voice: a two-wave examination. Acad Manag J 55(1):71–92
21. Lin B (2010) Study of the relationship between shynes and employe voice behavior: the moderating role of managerial opennes and psychological empowerment. Chin J Appl Psychol 16:235–242 (in Chinese)
22. Lin SHJ, Johnson RE (2015) A suggestion to improve a day keeps your depletion away: examining promotive and prohibitive voice behaviors within a regulatory focus and ego depletion framework. J Appl Psychol 100(5):1381
23. Liu W, Zhu R, Yang Y (2010) I warn you because i like you: voice behavior, employee identifications, and transformational leadership. Leadersh Q 21(1):189–202
24. Premeaux SF, Bedeian AG (2003) Breaking the silence: the moderating effects of self-monitoring in predicting speaking up in the workplace*. J Manag Stud 40(6):1537–1562

25. Senay I, Usak M, Prokop P (2015) Talking about behaviors in the passive voice increases task performance. Appl Cognit Psychol 29(2):262–270
26. Sun ZT (2013) The empirical research on voice behavior in chinese organizational context. Henan University, Master thesis (in Chinese)
27. Tangirala S, Ramanujam R (2008) Exploring nonlinearity in employee voice: the effects of personal control and organizational identification. Acad Manag J 51(6):1189–1203
28. Van Dyne L, LePine JA (1998) Helping and voice extra-role behaviors: evidence of construct and predictive validity. Acad Manag J 41(1):108–119

Chapter 41
The Research of Competitiveness Evaluation Indicators on Chinese OTA Websites Based on OWA and Intuition Fuzzy Theory

Yong Huang, Lili Jiang, Jian Liu, Ronghua Zhu and Liang Zhao

Abstract With the popularization of the Internet, Online Travel Agent (OTA) market is developing rapidly and has become the focus of tourism research due to the increasingly fierce competition in the market. Applying Porter's five forces model, this paper proposes seven indicators of the competitiveness evaluation on Chinese OTA websites. Then intuition fuzzy theory, combined with Ordered Weighted Aggregation (OWA), is utilized to evaluate the competitiveness of the OTA websites. Through empirical analysis, the importance of indicators is sorted, and the top four indicators are product value, trust, web design and personality. Finally, suggestions for improving competitiveness are put forward on the basis of empirical analysis.

Keywords OTA · Competitiveness evaluation indicators · OWA · Intuition fuzzy theory

41.1 Introduction

In recent years, Online Travel Agent (OTA) market is developing rapidly with the popularity of the Internet. Chinese OTA websites blossom fast, such as Ctrip, eLong, Tuniu, Qunar, etc. However, the competition in this market is becoming increasingly fierce. The data released by the China Tourism Research Institute [1] shows that Chinese OTA market transactions amounted to 307.79 billion Yuan in 2014, implying an increase of 38.9 percent over the previous year, and it will continue maintaining the trend in the next few years. As an important carrier of tourism e-commerce transactions, OTA websites provide tourists with different ways in information search, tourist destinations perception, tourism planning decision-making and travel product purchase. With the rapid growth of online users and transactions, OTA websites play the growing important role in tourism development.

Y. Huang · L. Jiang (✉) · J. Liu · R. Zhu · L. Zhao
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: 1093678534@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_41

Despite large number of Chinese OTA websites appeared, travel products have serious homogeneity. For instance, they contain similar flights, hotels and holiday products. When users select the websites, they often make decisions depending on websites' trust which is usually based on their reputation. For little-known OTA websites, trust is an important factor in determining their competitiveness. Even in order to gain more users, vicious competition such as price war appeared between the OTA websites. Therefore, to obtain more users, competitiveness of OTA website needs to be improved.

The remainder of this article is organized as follows. First, the research method of this paper is introduced, including construction competitiveness indicators of OTA websites, OWA based on the normal distribution and intuition fuzzy theory. Second, empirical analysis on competitiveness factors of OTA websites is made accordingly, and suggestions for improving competitiveness are put forward. Finally, conclusions and directions for further research are derived.

41.2 Literature Review

Scholars have studied on OTA from various aspects. Cibinskiene and Snieskiene [3] carried out the evaluation of city tourism competitiveness using the methods of qualitative and quantitative analysis, and selected the main factors for the evaluation of city tourism competitiveness following the logic of the conceptual model of city tourism competitiveness. And it estimated the importance of internal and external environment factors in form of weight coefficients through the analysis of expert evaluation results. Chee-Hua, Chin et al. [2] examined the impact of multi-environmental components towards development of tourism destination competitiveness from local communities' perspective and revealed that both cultural heritage attractions and natural resources found to have positive impact towards development of destination competitiveness from local communities' perspective. Martínez et al. [7] presented from a theoretical point of view, public policies and tourism marketing as determinant factors of competitiveness in tourism and presents the results of a field study on the subject held in the cities of Morelia, Mexico and Alcala de Henares, Spain. Cîrstea [4] realized a study of tourism competitiveness among the top 15 most competitive countries from the economic perspective as The Global Competitiveness Report present them, and aimed to identify the correlation between tourism competitiveness indicator. Roger-Monzó et al. [8] tested how to use online consumer loyalty to gain competitive advantage in travel agencies. Shen [9] selected seven OTA websites in China and established a set of OTA websites evaluation system by combining TOPSIS with AHP to take horizontal measurement research of the samples. Weng and Ning [11] constructed the evaluation index system of OTA development potential from three dimensions and analyzed the development of 11 Online Travel Agents using multi-index maximum deviation and clustering analysis methods. Su and Wang [10] proposed the factors which influence the competition of e-business tourism with principle factor analysis. Hao et al. [5] developed a genetic algorithm-based learning approach to explore customer satisfaction and their preferences.

There are many applications utilizing intuition fuzzy theory and OWA operator in the indicators evaluation study. American scholar Yager [13] came up with an ordered weighted aggregation (OWA) operator to aggregate information. The features of OWA are that data in descending order is weighted integration and weight is only connected with the ith position. Xu [12] proposed discrete normal distribution according to the normal distribution. Through this approach, the middle value is assigned to the greater weights and larger and smaller values are assigned to the smaller weights. Yu et al. [14] proposed loss reasons index based on the transaction process between E-commerce and customers, and estimated these reasons by intuitionistic fuzzy theory. Huang et al. [6] evaluated corporate social responsibility (CSR) and developed a novel Intuitionistic Fuzzy Importance-performance Analysis (IFIPA) for sport tourism event. And the IFIPA successfully offered the promising results than IPA and provided the reference for future sport tourism event analysis and practical suggestions for future sport tourism event organizations.

It is important to analyze competitiveness indicators of OTA websites in order to retain existing customers and attract new users to spread word of mouth. So far, the main research methods are AHP, fuzzy analytic hierarchy process and so on. However, these methods can't reflect support, opposition and hesitation at the same time. This paper utilizes OWA operator based on discrete normal distribution and intuition fuzzy theory. On the one hand, the larger and smaller values are given smaller weights based on the OWA operator of discrete normal distribution, so as to effectively avoid the impact of deviation of these values on evaluation results. On the other hand, intuition fuzzy expands the traditional fuzzy sets, considering membership, non-membership and hesitation degree, and it can describe more delicately, which makes the research more scientific and reasonable.

41.3 Method

41.3.1 Construct Competitiveness Indicators of OTA Websites

The functions of tourism websites are roughly classified into three aspects. The first is the introduction about attractions and expenses. The second is travel services for the intention of the customer, such as online booking and hotel reservations. The third is the functions about website hardware service, such as the Internet speed. Porter's five forces model is usually used to analyze the competition in an industry, and the five basic competitive forces are potential new entrants, competitive alternatives, buyers' bargaining ability, suppliers' bargaining ability and competition between existing competitors. Then Chinese OTA websites are analyzed based on Porter's five forces model, as shown in Fig. 41.1.

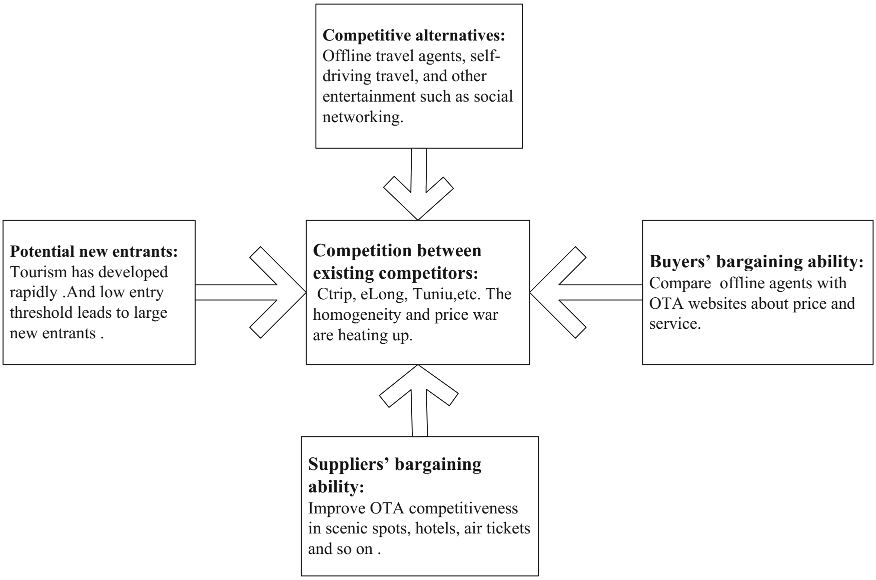


Fig. 41.1 The analysis of Chinese OTA websites based on Porter's five forces model

Applying Porter's five forces model, this paper concludes seven indicators of OTA websites competitiveness, combining the three main functions of OTA websites and summarizing OTA websites evaluation index mentioned in the literature review. The seven indicators are: personality, web design, product value, trust, marketing, interaction, and market capacity. For example, in order to keep market share and avoid homogenization, personality is concluded according to competitive alternatives and competition between existing competitors in the above model. The descriptions of indicators are as follows in Table 41.1.

41.3.2 OWA Operator Based on Discrete Normal Distribution

The formulas of calculating weights through discrete normal distribution are as follows:

$$w_i = \frac{\frac{1}{\sqrt{2\pi}\sigma_n} e^{-[(i-u_n)^2/2\sigma_n^2]}}{\sum_{j=1}^{n} \frac{1}{\sqrt{2\pi}\sigma_n} e^{-[(j-u_n)^2/2\sigma_n^2]}} = \frac{e^{-[(i-u_n)^2/2\sigma_n^2]}}{\sum_{j=1}^{n} e^{-[(j-u_n)^2/2\sigma_n^2]}} = \frac{e^{-[(i-(1+n)/2)^2/2\sigma_n^2]}}{\sum_{j=1}^{n} e^{-[(j-(1+n)/2)^2/2\sigma_n^2]}}, \quad (41.1)$$

$i = 1, 2, \ldots, n.$

Table 41.1 The descriptions of indicators

Indicator	Description
Personality	Websites have its own personalized features, and focus on some aspects to avoid homogenization
Web design	Whether web design is reasonable, beautiful and convenient, for example, station search, page navigation, browser suitability
Product value	Whether or not websites can provide users with high-quality information services, cost-effective, travel guide recommends, whether to provide personalized information services for the diversification of tourism demand, and whether to provide a competitive price
Trust	High reputation websites are generally able to obtain higher customer trust. The consumer usually feels safe by selecting a high reputation websites. Search engine ranking and websites listing reflect websites reputation
Marketing	Websites propaganda will affect their reputation. Diversified marketing, tourism forum links, website links and other travel agencies are also important factors in determining whether to retain users
Interaction	Interaction of OTA websites, especially the establishment of a virtual community can enhance customer loyalty
Market capacity	Online travel market capacity reflects the current development capacity of OTA. It includes OTA websites' search index, the number of microblog which websites published, amount of websites microblog fans and the number of visiting and the website covering

In this formula, n represents the number of assessment experts.

$$u_n = \frac{1+n}{2}, \quad \sigma_n = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(i-u_n)^2}. \tag{41.2}$$

41.3.3 Intuition Fuzzy Heory

Intuition fuzzy theory extends fuzzy set theory, considering the membership, non-membership and hesitation degree. Intuition fuzzy set can be more reasonable in describing the object fully than the traditional fuzzy sets.

For intuition fuzzy figure $\alpha = (u_\alpha - v_\alpha)$, it can be assessed by the score function:

$$S(\alpha) = u_\alpha - v_\alpha, \tag{41.3}$$

u_α represents membership, and is the non-membership.

Score function is dependent on the difference between membership and non-membership, and the greater the difference, the larger intuition fuzzy score function is.

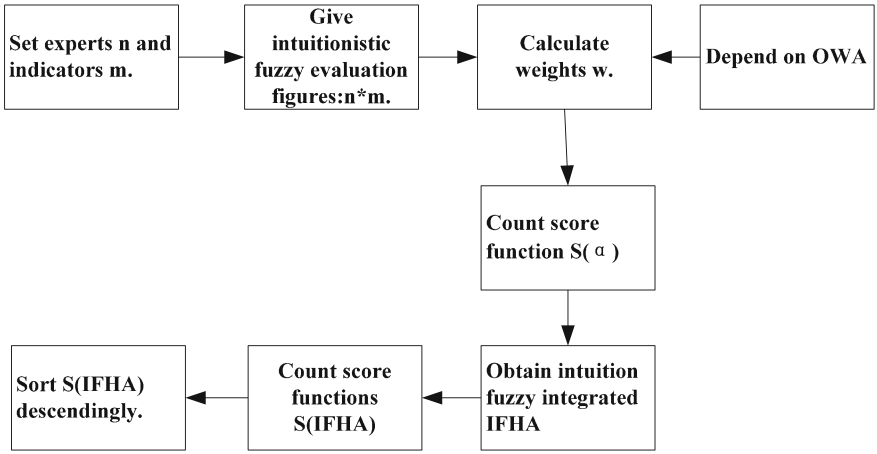


Fig. 41.2 Assessment method of competitiveness indicators on OTA websites

41.3.4 Evaluation of Competitiveness Indicators on OTA Websites

An assessment method is applied combining the above theories with competitiveness evaluation indicators on Chinese OTA websites, as shown in Fig. 41.2.

First, intuitionistic fuzzy evaluation figures (α) are given by experts and weights (w) are calculated. Second, score functions ($S(\alpha)$) are obtained, and sort α in term of $S(\alpha)$ in descending order. Third, α is empowered applying the weight w. Intuition fuzzy integrated $IFHA_j$ is obtained by the following formula.

$$\mathrm{IFHA_j} = \left(1 - \prod_{j=1}^{n} (1 - u_{\alpha_{\sigma(j)}})^{w_j}, \prod_{j=1}^{n} v_{\alpha_{\sigma(j)}}^{w_j} \right). \tag{41.4}$$

Finally, score functions $S(\mathrm{IFHA_j})$ are gained according to intuition fuzzy integrated $\mathrm{IFHA_j}$.

41.4 Empirical Analysis

41.4.1 Application

Step 1. Invite four university teachers who have been engaged in tourism research in Chengdu and a veteran tour guide. The total number is five, $n = 5$, $m = 7$.

Table 41.2 Fuzzy figures

Indicators	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5
Personality	(0.6, 0.3)	(0.7, 0.2)	(0.4, 0.4)	(0.3, 0.2)	(0.5, 0.1)
Web design	(0.6, 0.1)	(0.5, 0.1)	(0.4, 0.4)	(0.7, 0.1)	(0.6, 0.3)
Product value	(0.8, 0.1)	(0.9, 0.0)	(0.7, 0.2)	(0.6, 0.3)	(0.4, 0.3)
Trust	(0.7, 0.1)	(0.6, 0.2)	(0.4, 0.3)	(0.7, 0.0)	(0.5, 0.2)
Marketing	(0.5, 0.2)	(0.4, 0.4)	(0.6, 0.2)	(0.5, 0.4)	(0.4, 0.2)
Interaction	(0.5, 0.2)	(0.5, 0.4)	(0.4, 0.2)	(0.5, 0.5)	(0.3, 0.4)
Market capacity	(0.3, 0.3)	(0.3, 0.4)	(0.5, 0.3)	(0.6, 0.3)	(0.4, 0.3)

Step 2. Combined with the reality, fuzzy figures are given for each indicator by experts, in which expert 3 is a veteran tour guide, as shown in Table 41.2.

Step 3. Weights are calculated applying OWA based on the normal distribution (namely, formula (1)), $w = (0.112, 0.236, 0.304, 0.236, 0.112)$.

Step 4. Calculate score functions $S(\alpha)$

① Personality: $S_1(\alpha_1) = 0.6 - 0.3 = 0.3, S_1(\alpha_2) = 0.5, S_1(\alpha_3) = 0, S_1(\alpha_4) = 0.1, S_1(\alpha_5) = 0.4$. So, $S_1(\alpha_2) > S_1(\alpha_5) > S_1(\alpha_1) > S_1(\alpha_4) > S_1(\alpha_3)$. So, $\alpha_{\sigma(1)} = (0.7, 0.2), \alpha_{\sigma(2)} = (0.5, 0.1), \alpha_{\sigma(3)} = (0.6, 0.3), \alpha_{\sigma(4)} = (0.4, 0.4)$.

② Web design: $S_2(\alpha_1) = 0.6 - 0.1 = 0.5, S_2(\alpha_2) = 0.5 - 0.1 = 0.4, S_2(\alpha_3) = 0.4 - 0.4 = 0, S_2(\alpha_4) = 0.7 - 0.1 = 0.6, S_2(\alpha_5) = 0.6 - 0.3 = 0.3$. So, $S_2(\alpha_4) > S_2(\alpha_1) > S_2(\alpha_2) > S_2(\alpha_5) > S_2(\alpha_3)$. So, $\alpha_{\sigma(1)} = (0.7, 0.1), \alpha_{\sigma(2)} = (0.6, 0.1), \alpha_{\sigma(3)} = (0.5, 0.1), \alpha_{\sigma(4)} = (0.6, 0.3), \alpha_{\sigma(5)} = (0.4, 0.4)$.

③ Product value: $S_3(\alpha_1) = 0.8 - 0.1 = 0.7, S_3(\alpha_2) = 0.9 - 0.0 = 0.9, S_3(\alpha_3) = 0.7 - 0.2 = 0.5, S_3(\alpha_4) = 0.6 - 0.3 = 0.3, S_3(\alpha_5) = 0.4 - 0.3 = 0.1$. So, $S_3(\alpha_2) > S_3(\alpha_1) > S_3(\alpha_3) > S_3(\alpha_4) > S_3(\alpha_5)$. So, $\alpha_{\sigma(1)} = (0.9, 0.0), \alpha_{\sigma(2)} = (0.8, 0.1), \alpha_{\sigma(3)} = (0.7, 0.2), \alpha_{\sigma(4)} = (0.6, 0.3), \alpha_{\sigma(5)} = (0.4, 0.3)$.

④ Trust: $S_4(\alpha_1) = 0.7 - 0.1 = 0.6, S_4(\alpha_2) = 0.6 - 0.2 = 0.4, S_4(\alpha_3) = 0.4 - 0.3 = 0.1, S_4(\alpha_4) = 0.7 - 0.0 = 0.7, S_4(\alpha_5) = 0.5 - 0.2 = 0.3$. So, $S_4(\alpha_4) > S_4(\alpha_1) > S_4(\alpha_2) > S_4(\alpha_5) > S_4(\alpha_3)$. So, $\alpha_{\sigma(1)} = (0.7, 0.0), \alpha_{\sigma(2)} = (0.7, 0.1), \alpha_{\sigma(3)} = (0.6, 0.2), \alpha_{\sigma(4)} = (0.5, 0.2), \alpha_{\sigma(5)} = (0.4, 0.3)$.

⑤ Marketing: $S_5(\alpha_1) = 0.5 - 0.2 = 0.3, S_5(\alpha_2) = 0.4 - 0.4 = 0, S_5(\alpha_3) = 0.6 - 0.2 = 0.4, S_5(\alpha_4) = 0.5 - 0.4 = 0.1, S_5(\alpha_5) = 0.4 - 0.2 = 0.2$. So, $S_5(\alpha_3) > S_5(\alpha_1) > S_5(\alpha_5) > S_5(\alpha_4) > S_5(\alpha_2)$. So, $\alpha_{\sigma(1)} = (0.6, 0.2), \alpha_{\sigma(2)} = (0.5, 0.2), \alpha_{\sigma(3)} = (0.4, 0.2), \alpha_{\sigma(4)} = (0.5, 0.4), \alpha_{\sigma(5)} = (0.4, 0.4)$.

⑥ Interaction: $S_6(\alpha_1) = 0.5 - 0.2 = 0.3, S_6(\alpha_2) = 0.5 - 0.4 = 0.1, S_6(\alpha_3) = 0.4 - 0.2 = 0.2, S_6(\alpha_4) = 0.5 - 0.5 = 0, S_6(\alpha_5) = 0.3 - 0.4 = -0.1$. So, $S_6(\alpha_1) > S_6(\alpha_3) > S_6(\alpha_2) > S_6(\alpha_4) > S_6(\alpha_5)$. So, $\alpha_{\sigma(1)} = (0.5, 0.2), \alpha_{\sigma(2)} = (0.4, 0.2), \alpha_{\sigma(3)} = (0.5, 0.4), \alpha_{\sigma(4)} = (0.5, 0.5), \alpha_{\sigma(5)} = (0.3, 0.4)$.

⑦ Market capacity: $S_7(\alpha_1) = 0.3 - 0.3 = O, S_7(\alpha_2) = 0.3 - 0.4 = -0.1, S_7(\alpha_3) = 0.5 - 0.3 = 0.2, S_7(\alpha_4) = 0.6 - 0.3 = 0.3, S_7(\alpha_5) = 0.4 - 0.3 = 0.1$. So, $S_7(\alpha_4) > S_7(\alpha_3) > S_7(\alpha_5) > S_7(\alpha_1) > S_7(\alpha_2)$. So, $\alpha_{\sigma(1)} = (0.6, 0.3), \alpha_{\sigma(2)} = (0.5, 0.3), \alpha_{\sigma(3)} = (0.4, 0.3), \alpha_{\sigma(4)} = (0.3, 0.3), \alpha_{\sigma(5)} = (0.3, 0.4)$.

Table 41.3 The final result of sort

Indicators	Intuition fuzzy integration IFHA	Score S	Rank
Personality	(0.5125, 0.2076)	0.3049	4
Web design	(0.5662, 0.1514)	0.4148	3
Product value	(0.7441, 0)	0.7441	1
Trust	(0.6008, 0)	0.6008	2
Marketing	(0.4739, 0.2272)	0.2467	5
Interaction	(0.4580, 0.3313)	0.1267	6
Market capacity	(0.4205, 0.3098)	0.1107	7

Step 5. Calculate intuition fuzzy IFHA according to formula (41.4). Personality: $\text{IFHA}_1 = (1-(1-0.7)^{0.112} \times (1-0.5)^{0.236} \times (1-0.6)^{0.304} \times (1-0.3)^{0.236} \times (1-0.4)^{0.112}, 0.2^{0.112} \times 0.1^{0.236} \times 0.3^{0.304} \times 0.2^{0.236} \times 0.4^{0.112}) = (0.5125, 0.2076)$, web design: $\text{IFHA}_2 = (0.5662, 0.1514)$, product value: $\text{IFHA}_3 = (0.7441, 0)$, trust: $\text{IFHA}_4 = (0.6008, 0)$, marketing: $\text{IFHA}_5 = (0.4739, 0.2272)$, interaction: $\text{IFHA}_6 = (0.4580, 0.3313)$, market capacity: $\text{IFHA}_7 = (0.4205, 0.3098)$.

Step 6. Calculate score functions in terms of IFHA (formula (41.3)). Personality: $S_1(\text{IFHA}_1) = 0.5125 - 0.2076 = 0.3049$, web design: $S_2(\text{IFHA}_2) = 0.4148$,
product value: $S_3(\text{IFHA}_3) = 0.7441$, trust: $S_4(\text{IFHA}_4) = 0.6008$, marketing:
$S_5(\text{IFHA}_5) = 0.2467$, interaction: $S_6(\text{IFHA}_6) = 0.1267$, market capacity: $S_7(\text{IFHA}_7) = 0.1107$.

Step 7. Sort $S(\text{IFHA}_j)$ in descending order and obtain the final result, as shown in Table 41.3.

As seen from the table, the importance of competitiveness evaluation indicators in descending order is: product value > trust > web design > personality > marketing > interaction > market capacity. It is not hard to see that the user most pays attention to the product value when choosing OTA websites. That is, whether or not websites can provide users with high-quality information services, cost-effective, travel guide recommends, whether to provide personalized information services for the diversification of tourism demand, and whether to provide a competitive price.

41.4.2 *Suggestions*

The recommendations in terms of evaluation are as follows.

First, the product value of OTA websites should be improved. They can offer high-quality information service and competitive price. It is necessary to provide personalized information services for the diversification of tourism demand. For example, many people advocate self-driving travel, and it is a way to provide personalized service in the travel process and to personalize private tour guide.

Next suggestions are about the trust, web design and personality. The reputation and ranking of websites in search engines will directly affect the user's trust. Reasonable, beautiful and convenient websites design can enhance customer loyalty. Personalization is the key to a lasting website. Now the main services of OTA websites contain hotels, flights, vacation. Focused in some service is the key to achieving a distinctive website. For instance, some websites emphasize vertically integrated services, some focus on travel, and some pay more attention to hotel booking, some stress travel community by mobile Internet.

Finally, marketing campaign is very important to improve the reputation of websites. Meanwhile, strengthening the advertising investment and taking advantage of new media such as microblog and wechat are also very important ways.

41.5 Conclusions

In the era of rapid development of the Internet, the "Internet plus tourism" has become the focus of tourism development and how to improve the competitiveness of OTA websites is the key factor. Porter's five forces model and intuition fuzzy theory combining with Ordered Weighted Aggregation are utilized to evaluate the competitiveness of the OTA websites. Through empirical analysis, we can see that the importance order of competitiveness indicators of OTA websites are product value, trust, web design, personalization, marketing, interaction, market capacity. And recommendations for improving competitiveness on the basis of the evaluation results are proposed. However, this study only considers the membership and non-membership. In future research, hesitation degree can be added, and it will enhance the reliability of competitiveness assessment.

References

1. China Tourism Development Report (2015) Wuhan branch of China tourism academy
2. Chin CH, Lo MC, Songan P, Nair V (2014) Rural tourism destination competitiveness: a study on Annah Rais Longhouse Homestay, Sarawak. Procedia-Soc Behav Sci 144:35–44
3. Cibinskiene A, Snieskiene G (2015) Evaluation of city tourism competitiveness. Procedia-Soc Behav Sci 213:105–110
4. Cîrstea ŞD (2014) Travel and tourism competitiveness: a study of world's top economic competitive countries. Procedia Econ Financ 15:1273–1280
5. Hao JX, Yu Y et al (2015) A genetic algorithm-based learning approach to understand customer satisfaction with OTA websites. Tour Manag 48:231–241
6. Huang FH, Ye YJ, Kao CH (2015) Developing a novel intuitionistic fuzzy importance-performance analysis for evaluating corporate social responsibility in sport tourism event. Expert Syst Appl 42:6530–6538

7. Martínez RM, Galván MO, Lafuente AMG (2014) Public policies and tourism marketing. An analysis of the competitiveness on tourism in Morelia, Mexico and Alcala de Henares. Spain. Procedia-Soc Behav Sci 148:146–152
8. Roger-Monzó V, Martí-Sánchez M, Guijarro-García M (2015) Using online consumer loyalty to gain competitive advantage in travel agencies. J Bus Res 68(7):1638–1640
9. Shen Z (2015) The research of services of OTA websites based on AHP and TOPSIS. Special zone economy, pp 113–116 (In Chinese)
10. Su G, Wang Q (2014) Studying on enhancing the competitiveness of tourism e-business in Shanxi. Economic problems, pp 122–125, (In Chinese)
11. Weng G, Ning N (2015) Development potential evaluation and application research of OTA in China. Commer Res 1:025
12. Xu Z (2005) An overview of methods for determining OWA weights. Int J Intell Syst 20(8):843–865
13. Yager RR (1988) On ordered weighted averaging aggregation operators in multicriteria decisionmaking. IEEE Trans Syst Man Cybern 18(1):183–190
14. Yu X, Cao J, Zhang M (2012) Evaluation reasons of B2C e-commerce customer churn. Fuzzy Syst Math 26:166–172 (In Chinese)

Chapter 42
Comparing the Efficiency of Public-Private Partnerships with the Traditional Procurement: Based on the Chengdu No. 6 Water Plant B

Chuan Chen, Ping Chen and Qi Wang

Abstract The central government has done its best to implement the Public-Private Partnerships (PPP). However, the government policy-makers, practitioners and researchers have little knowledge about whether the PPP procurement is more efficient for China when compared with the traditional procurement. The Chengdu No. 6 Water Plant B is an important and classical BOT project in China and it is nearly to be transferred to Chengdu government. So this paper did a Value for money (VFM) analysis on the Chengdu No. 6 Water Plant B to measure the efficiency of it. The results indicate that the Chengdu No. 6 Water Plant B should be purchased by PPP mode rather than by traditional mode. That is, the PPP procurement is prove to be more efficient than the traditional procurement. Given that the Chinese government is now promoting a wider range and larger scale of private participation in the infrastructure sector, this research is of vital and timely significance.

Keywords Public-private partnerships · Value for money · Chengdu No. 6 Water Plant B · China

42.1 Introduction

In recent years, due to the increasing pressure of the economic downturn, infrastructure has been the breach and key to achieve the steady growth of the Chinese economy. With the reformed tax, lowered land revenues and increased demand of the infrastructure, the financial of local governments is in the starved condition. As a result, to alleviate the financial pressure of government, enhance the efficiency of infrastructure construction and operation, and meet the development demand of eastern and western society and economy, the central government has done its best to implement the PPP (Public-Private Partnerships).

C. Chen · P. Chen (✉) · Q. Wang
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: chenping1026@foxmail.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_42

With the development of PPP in China, the PPP mode has been used in transport, energy, ports, water and so on [7, 8]. There are many attentions have been paid to PPP. Some researchers focus on the implementation context of PPP [6, 10]. For example, Zhang [14] explored the factors that drive the dissemination of liberalization policies and affect the current balance between private and public sector forces in an emerging economy. In addition, Zhang and Gao [13] developed a theoretical framework of PPP governance, identifying the logics and interactions of the differentiating levels in the PPP system. Meanwhile, some other researchers focus on the risks of PPP in China [2, 11]. For example, Xu and Chan [12] presented a detail study of critical risk factors affecting the implementation of PPP waste-to-energy projects in China. In a summary, previous researches did not pay much attentions to whether the PPP mode is be more efficient than the traditional mode. As a unique project implementation mode, we should focus on that whether the PPP is more efficient than traditional procurement, avoiding unnecessary financial burden on government by excessive PPP-seeking.

This paper tried to explore whether the PPP mode is more efficient than the traditional mode. Given that the Chinese government is now promoting a wider range and larger scale of private participation in the infrastructure sector, this research is of vital and timely significance. First, it proves that PPP procurement is more efficient than the traditional procurement, which prove theoretical base for prevalently extending PPP in China. Second, the VFM analysis has been employed to justify the PPP mode, and it can be used in other projects by both public sector and private sector who participate in a PPP project.

The structure of this paper are as follows. Section 42.1 begins with a brief review of the literature on the PPP. Section 42.2 gives a background that Chinese government has done its best to implement the PPP, describing that it is urgent and vital to use the VFM assessment to compare the efficiency of PPP procurement with the traditional procurement. Section 42.3 gives an overview of the VFM assessment, which contains the qualitative evaluation and quantitative evaluation. Section 42.4 utilizes the VFM assessment to analyze the performance measurement of the Chengdu No. 6 Water Plant B project, which is based on the survey results. Finally, the paper discusses the key findings from the case study and then concludes with recommendations for the future.

42.2 Background

PPP is a mode which the government and one or more private sector companies provide the public projects or services through a partnership. PPP involves a contract between a public sector authority and a private party, in which the private party obtains profits by providing a public service or project and assumes substantial financial, technical and operational risk in the project.

On the Eighteenth National Congress of the Communist Party of China, the issue that let markets play a decisive role in allocating resources lay the theoretical foundation for the popularization of the PPP. After the national financial meeting, Finance Minister Lou Jiwei made a report about PPP, giving the high expectations about the significant effect of PPP in the modernization of national governance and financial system. The Ministry of Finance (MOF) appointed a Working Party on May 26, 2014, and established the PPP center in Dec. 2014. The National Development and Reform Commission (NDRC) launched 80 PPP demonstration projects in May 2014, while the Ministry of Finance confirmed 30 PPP demonstration projects in Nov. 2014. With the continuous deep exploration of PPP, the MOF and NDRC have passed the legislation work, established the working group and published a number of important policy documents.

Ironically, despite the fact that many BOT or PPP projects have been kicked off yearly since the first inception of these innovative project delivery methods, very few such projects have actually run through to completion. This is either because of the relatively long concession period or because of premature project cancellation or suspension. This situation has left limited empirical evidence by which decision makers, practitioners and scholars can justify the PPP method, particularly in China.

With the growing number of PPP projects in China, increasingly agencies want to know whether the PPP mode is more efficient than traditional procurement. Value for money (VFM) has been used as a tool to compare the efficiency of pursing a project as a PPP or traditional procurement [5], and has been widely used in the United Kingdom, Australia, Korea, but it is little known in China. The Chengdu No. 6 Water Plant B is located in Chengdu City, Sichuan Province, China. It is an important pilot BOT project which is one kind of PPP project. It provides a rare case project of its kind by which to scrutinize the determinants that differentiate a successful BOT project from an unsuccessful or less successful one [4] and there are so many water BOT projects have been benchmarked to it during the past two decades [3]. Hence, it is a good and representative case deserved deeply study.

42.3 Method

Value for money is defined as the optimum combination of whole-of-life costs and quality (or fitness for purpose) of the good or service to meet the user's requirement. The term whole-of-life is used to refer to the life cycle of the good or service. VFM is not the choice of goods and services based on the lowest cost bid [9]. Considering that public projects are necessary construction which the government can perform its duties and achieve social benefits, the VFM assessment should ensure the government focus on the economic costs and social benefits in the project purchase stage.

The VFM assessment provides a basis for project procurement mode selection, and tracks and evaluates the project value in the whole life cycle. It contains the quantitative and qualitative evaluation. What's more, it would be repeated through the decision making stage, purchase stage and even the whole of life. Figure 42.1 summarizes the procedure of VFM assessment.

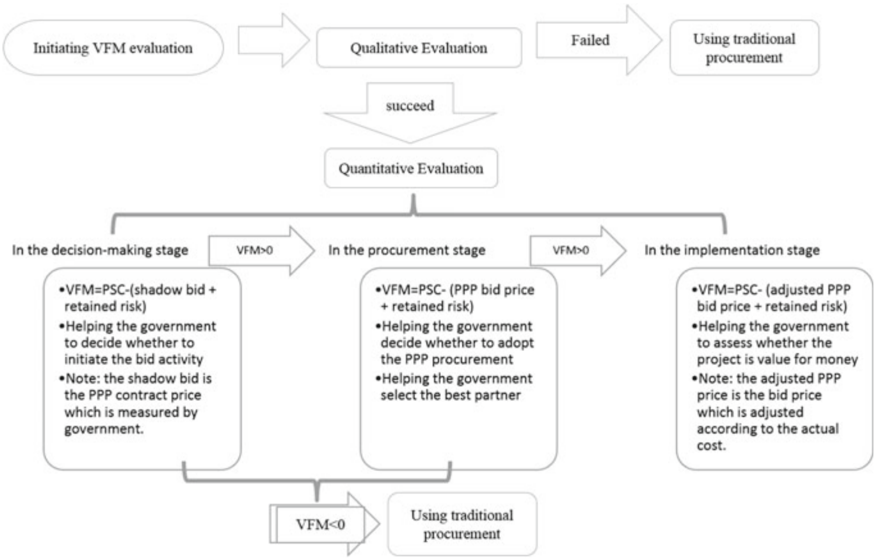


Fig. 42.1 The procedure of VFM assessment

42.3.1 VFM Qualitative Evaluation

The qualitative evaluation of the VFM involves the factors that are unable to quantify. Based on international experience, these factors are generally divided into the viability, desirability and achievability. The viability means that the product and service stipulated in the contract could meet the public demand, which also considering the fairness and efficiency of the PPP procurement. The desirability means that the PPP procurement has the advantage compared with the traditional procurement, and its profit would make up the costs and insufficiency. The achievability means that the private sectors have enough interests in target project, and the government and the private sectors have enough resource and ability to promote the project implementation.

42.3.2 VFM Quantitative Evaluation

The quantitative evaluation of the VFM assessment compares the project life cycle net present cost of government in pursuing a project as a traditional procurement with the cost of pursuing a project as a PPP, and then selects the procurement pattern of low cost with high benefit and high efficiency. No matter which procurement pattern selected, it assumed that the project has the same outputs, effects and influence. Hence, the lower net present cost of procurement mode would be chosen.

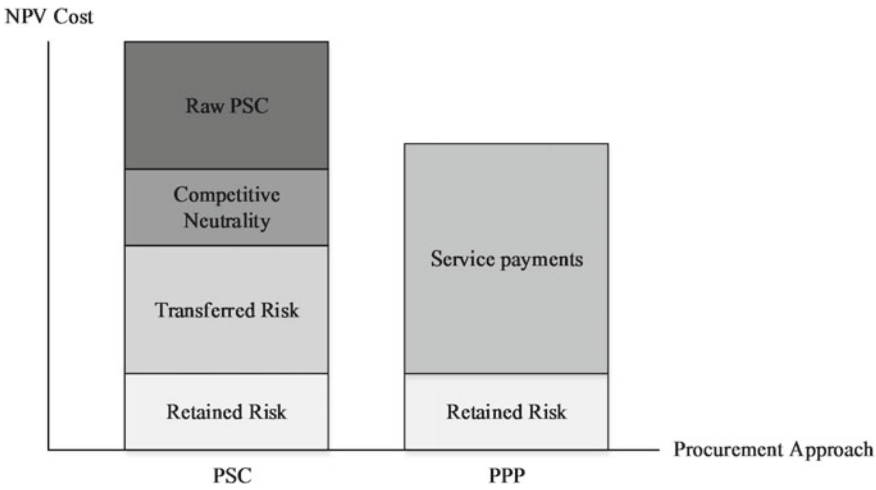


Fig. 42.2 The theoretical model

The steps of the quantitative evaluation are as follows: (1) Calculate the net present cost of PPP, also called PPPs; (2) Calculate the Public Sector Comparator (PSC); (3) VFM = PSC *C* PPPs = PSC − (service payments + Retained Risk). If VFM > 0, the project would be pursued as a PPP; if VFM < 0, the project would be pursued as a traditional procurement. Figure 42.2 summarizes the procedure for calculating VFM.

(1) PPPs

The PPPs estimates the public sector's cost of pursuing a project as a PPP procurement.

① The PPPs of different project stage

In the project decision-making stage, the actual cost of pursuing a project as a PPP is unknown, therefore it often uses the shadow bid as the net present cost. The shadow bid is the PPP contract price which is measured by government according to the historical data. As a result, the PPPs equals the sum of the shadow bid and the retained risk by the government. In this stage, the VFM assessment would help the government to decide whether to initiate the bid activity.

In the procurement stage, the PPPs equals the sum of the PPP bid price and the retained risk by the government. In this stage, the VFM assessment would help the government decide whether to adopt the PPP mode to purse the project. In addition, it would make the government find the best partner from large number of bidders.

In the implementation stage, the PPPs equals the sum of the adjusted PPP bid price and the retained risk. The adjusted PPP price is the bid price which is adjusted according to the actual cost. In this stage, the VFM assessment would help the government to assess whether the project is value for money.

In the whole life cycle stage, the PPPs equals the sum of the service payments paid by the government.

② Calculate the risk costs

The steps of calculating the risk costs:

- Identify risks: we should identify the all possible risks and on this basis to identify the important risk or portfolio risk;
- Quantify the value of risk effect: we should evaluate the consequence and the time of every risk, then make assumptions with a certain value;
- Evaluate the likelihood of every risk: we should evaluate the probability of every risk with a certain value;
- Calculate the value of risk: the value of every risk = the consequence × the probability + the flexible factor.

The PPP mode involves the interests of both public sectors and private sectors. As a result, the risk allocation and transferred is one of the core driven factors of the VFM of the PPP.

From the government standpoint, there are three strategies of risk allocation:

- transferred risk, namely that the government transfer risks to the private sector and encourage them employing innovative delivery under the PPP procurement;
- retained risk, namely that the government retain and take risks;
- share risks, namely that the government and the private sector share the risks that are uncertain and difficult to manage.

Generally, the government will use integrated risk allocation strategies in the risk allocation. Furthermore, the government will allocate the risk to the one who are best positioned to manage and control it.

(2) Public Sector Comparator

The public sector comparator (PSC) estimates the public sector's cost of pursuing a project as a traditional procurement, meaning that the governments finance, own, implement the project all alone. The PSC is based on the required output specification and planned risk allocation of the project, which is adjusted for the whole-of-life risk under that the government takes the most efficient procurement mode.

The PSC includes four fundamental elements:

- Raw PSC;
- Competitive Neutrality;
- Transferred Risk;
- Retained Risk.

These components highlight that a PSC represents that the life cycle cost of government, which provides the infrastructure and service required by the project output under the traditional procurement. The key characteristics of the PSC are that:

- it is expressed as the net present cost of a projected cash flow based on the project specific discount rate over the life of the contract;
- it includes an adjustment of the competitive neutrality;
- it represents the most efficient procurement of the public sector;

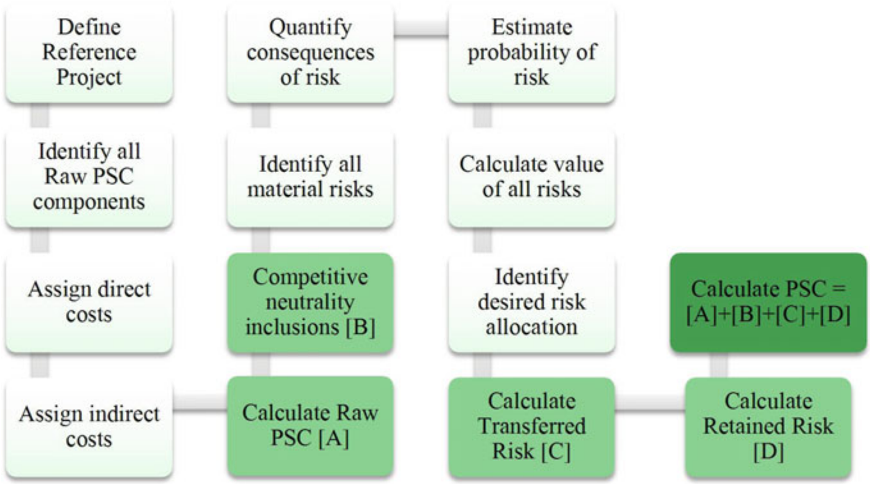


Fig. 42.3 The theoretical model

- it contains the risk value transferred to the private sectors as well as the risks retained by the public sectors [1].

Fig. 42.3 summarizes the steps of calculating the PSC.

① Define Reference Project

The reference project is the virtual project provided by the government with the traditional procurement, which matches the outputs and requirements of the PPP projects. To define the reference project, we should follow these principles:

- we need not to suppose that the governments undertake the all procurement;
- the procurement scope of the reference project should be the same as the project under the PPP purchase;
- it reflects the actual estimating of the project provided by the government under the most efficient delivery.

② Calculate the Raw PSC

The Raw PSC is the cost estimation of the government delivery, which is not considering the competitive neutrality and risks. It includes:

- direct cost, which represents the costs that could be traced or assigned the specific service;
- indirect cost, which represents the costs that are not directly related to the production of the services;
- minus all the identifiable third-party revenue [1].

$$\text{Raw PSC} = \text{construction cost} + (\text{operation cost} - \text{third-party revenue}),$$

$$\text{Construction cost} = \text{direct construction cost} + \text{indirect construction cost},$$

$$\text{Operation cost} = \text{direct operation cost} + \text{indirect operation cost}.$$

The steps of calculating the Raw PSC:

- identify the component of the Raw PSC, which includes the all costs of lifetime forecast, and we should concentrate on cash flows rather than the profits;
- allocate the direct cost, which includes identifying and calculating the all direct costs;
- allocate the indirect cost, which includes identifying and calculating the all indirect costs;
- calculate the Raw PSC, which includes merging the cash flows of the various stages and subtracting the third-party revenue.

③ Calculate the competitive neutrality

The aim of the competitive neutrality is eliminating the competitive edge and competitive disadvantage of the government due to the public-ownership system. As a result, the government and the private sectors would have the fair and similar basis for comparison during the quantitative analysis of VFM.

The competitive advantage of the government includes:

- the circulation tax, income tax, property tax and behavior tax only paid by the private sectors;
- the cost incurred under approval requirements and procedures only complied by the private sectors;
- the cost of the labor administration service, office space, market and IT service, which only paid by the private sectors.

The competitive disadvantage of the government includes the more rigorous monitoring and higher report cost faced by the public sectors.

④ Calculate the risk costs

The steps of calculating the risk costs of PSC are the same as the PPPs.

42.4 Case Study

To further expand the opening up to the outside and financing source of infrastructure construction, ease the financial burden on the government and build a justifiable financing system, the SPC launched 3 BOT pilot projects to the foreign investors, which included the Chengdu No. 6 Water Plant B project. Through an international open bidding in 1996, Veolia from France and Marubeni from Japan were selected, and then they formed a special purpose vehicle to finance and construct the water plant. The concession period is 18 years, including the construction period of 2.5 years and operation period of 15.5 years [3]. In addition, the project would be transferred to government in 2017.

42.4.1 VFM Qualitative Evaluation

(1) Viability

According to the score from experts, the value of the viability is 85.3 (See Table 42.1). It shows that the outputs and service of the Chengdu No. 6 Water Plant B project meets the public demand. In addition, the project company has the enough fairness.

(2) Desirability

According to the score from experts, the value of the desirability is 90.19 (See Table 42.2). It shows that the Chengdu No. 6 Water Plant B adopts the PPP procurement which has the advantage compared with the traditional procurement, and its profit would make up the costs and insufficiency.

Table 42.1 The viability of the Chengdu No. 6 Water Plant B project

Index	Weight	Value
Whether the project outputs are measured objectively and clearly defined in the agreement?	0.1	86.3
Whether the quality of project outputs can be measured objectively?	0.1	90.5
Whether the project outputs match the public demand?	0.1	92.4
Whether the appointed time according to the contract meets the requirements that the project outputs would supply continuously?	0.1	83.6
Whether the government could affect the public demand by changing the price of the project outputs and service in operating stage?	0.2	70.5
Whether the PPP procurement isn't appropriate because of the fairness and efficiency?	0.2	85.4
Whether the government will be able to ensure that it will pay to private sectors on time?	0.2	94.2
Total	1	85.3

Table 42.2 The desirability of the Chengdu No. 6 Water Plant B project

Index	Weight	Value
Whether the private sectors have enough ability to manage the risks?	0.3	93.1
Whether the payment mechanisms and contract terms would stimulate the private sectors manage the project risks efficiently?	0.2	91.2
Whether there is some room for flexibility in the project scope?	0.1	89.5
Whether there is any limit of the situation and disposal of the assets when the concession period finished?	0.2	83.8
Whether the government could evaluate the project outputs independently according to the standard by agreement?	0.1	88.6
Whether the design, construction and operation could be integrated?	0.1	94.5
Total	1	90.19

Table 42.3 The achievability of the Chengdu No. 6 Water Plant B project

Index	Weight	Value
Whether there is a market that could provide the project outputs for the private sectors?	0.1	90.1
Whether the private sectors have enough interests in the target project?	0.1	91.2
Whether the private sectors delight with the profit of the target project?	0.2	85.8
Whether the government has enough ability to carry out the contract management?	0.1	89.9
Whether the government has enough ability to manage the retained risk?	0.2	95.4
Whether there are more than one private sector could complete the project?	0.1	94.5
Whether the target project is attractive enough that a number of private sectors would bid for the project?	0.2	90.4
Total	1	90.89

(3) Achievability

According to the score from experts, the value of the achievability is 90.89 (See Table 42.3). It shows that the private sectors have enough interests in the Chengdu No. 6 Water Plant B, and the government and the private sector have enough resource and ability to promote the project implementation.

42.4.2 VFM Quantitative Evaluation

The Chengdu government adopts traditional mode to purse Chengdu No. 6 Water Plant C, and it has a same similar size with the Plant B to provide 400 thousand cubic meters per day. Hence, we use the data of Plant C to calculate PSC. Because the operation period of the Plant B is 15.5 years, we suppose that the operation period of the Plant C is 15.5 years. All operating cash flows are assumed to be paid at the end of each period.

(1) Raw PSC

The cost data was taken from the Chengdu No. 6 Water Plant C, which was pursued by government through the traditional procurement. And the two plant have the same production capacity. Table 42.4 shows the Raw PSC split into construction cost and operating costs (NPV basis).

(2) Competitive neutrality

Competitive neutrality assumptions are based on the income tax of every year (See Table 42.5). According to calculations, the NPV of the competitive neutrality adjustment is 130.81 million yuan.

Table 42.4 The Raw PSC

Cost Item		NPV (million yuan)
Construction costs		
Direct construction costs	Project construction costs	64.35
	Equipment costs	119.94
	Project installation costs	550.2
	Site preparation cost	5.8
	Land acquisition and compensation costs	55.1
	The land acquisition costs of the water transportation mains	76.44
	Design costs	12.09
	Investigation costs	3
	The costs of compiling the working drawing estimate	1.21
	The costs of compiling the as-built drawings	0.54
	Other fees of the engineering construction	3.68
Indirect construction costs	Overhead expenses of building units	5.88
	Personnel training costs	0.21
	The office and accommodation furniture costs	0.06
	Joint commissioning costs	1.17
	Electricity paste costs	1.6
	Engineering construction supervision costs	4.63
	Construction quality supervision costs	1.1
	The costs of the preparatory work of design	3
	The subordinating expenditures of imported equipment	3.67
	Overseas visit costs	1.15
	Basic reserve funds	92.44
	The price rising costs during the construction period	155.25
	Loan interest at home and abroad during the construction period	161.52
	The current funds	5.7
	Total construction costs	1329.75
Operation costs		
Direct operation costs	Water resources fees Electric charge	132.33 34.53
	Maintenance costs	373.75
	Pharmaceutical costs	90.4
Indirect operation costs	salaries and welfare costs	5.75
	Overhead expenses	138.07
	The loan interest of floating capital	8.65
	Loan interest	439.13
	Total operation costs	1222.6
	Raw PSC	2552.34

Table 42.5 The income tax (from 2002 to 2017)

Year	IncomeTax (million yuan)	Year	IncomeTax (million yuan)
2002	8.51	2010	19.91
2003	9.94	2011	21.34
2004	11.36	2012	22.76
2005	12.78	2013	22.48
2006	14.2	2014	23.01
2007	15.64	2015	23.14
2008	17.07	2016	23.26
2009	18.49	2017	11.69

Table 42.6 The NPV of the transferred risk and retained risk

Cost Item		NPV (million yuan)
Transferred risk	Land compensation	13.15
	Cost overruns	245.24
	Increases in financing costs	0
	Time delay	121.03
	Quality risk	117.24
	Contractor default	127.4
	Default by the concessionaire	1.27
	Environment damage during the construction period	6.15
	Nature force majeure during the construction period	0.03
	Concession company default	0.77
	Termination of concession by the concessionaire	0.72
	Environmental damage during the operation period	12.23
	Natural force majeure during the operation period	0.02
	Labor risk	0.58
	Technology risk	21.5
	Condition of facility(maintenance)	69.14
	Inflation risk	6.25
	Interest rate	277.62
	Foreign currency availability	0.3
	Foreign currency exchange rate (in construction)	0.02
	Foreign currency exchange rate (in operation)	0.24
	Foreign currency convertibility and remittance	0.3
	Development approvals	13.15
	Adverse government action or inaction	1.79
	Increase in taxes	65.95
	Total transferred risk	1102.08

(continued)

Table 42.6 (continued)

Cost Item		NPV (million yuan)
Retained risk	revoke, expropriation, sequestration	90.16
	Exclusivity, i.e., no second facility	0.89
	Change in law	119.48
	Development approvals	13.15
	Adverse government action or inaction	1.19
	Provision of utilities	1.19
	Increase in taxes	0.6
	Political force majeure events	19.84
	Termination of concession by government	49.61
	Payment failure by municipal utilities	641.92
	Land acquisition	13.15
	Environment damage	1.27
	Protection of geological and historical objects	6.15
	Non-natural force majeure	0.03
	Government department default	0.48
	Termination of concession by the concessionaire	1.43
	Non-natural force majeure	36.68
	Labor risk	0.58
	Insufficient revenue	644.12
	Fluctuating demand of water treated	162.32
	Delivery failure	0.06
	Problem in bill collection	162.32
	Raw water supply	162.32
	Foreign currency exchange rate (in operation)	0.24
	Foreign currency convertibility and remittance	0.3
	Total retained risk	2129.49

(3) Transferred risk and Retained risk

The NPV of the total transferred risk is 1102.08 million yuan, and the NPV of total retained risk is 2129.49 million yuan (See Table 42.6).

(4) PSC

$$\begin{aligned} \text{PSC} &= \text{Raw PSC} + \text{ Competitive neutrality} + \text{Transferred risk} + \text{Retained risk} \\ &= 5914.72 \text{ million yuan.} \end{aligned}$$

So the PSC of the Chengdu No. 6 Water Plant B is 5914.72 million yuan.

Table 42.7 The costs paid by Chengdu Water Supply Company

Year	Cost (million yuan)	Year	Cost (million yuan)
2002	128.88	2010	212.69
2003	157.21	2011	210.11
2004	172.9	2012	209.64
2005	186.37	2013	206.97
2006	198.52	2014	203.59
2007	207.42	2015	199.96
2008	205.86	2016	201.37
2009	209.88	2017	121.91

(5) Service payments

Table 42.7 shows the costs paid to the project company of Chengdu No. 6 Water Plant B during the operation period, which is undertaken by Chengdu Water Supply Company.

According to calculations, the NPV of the costs paid by Chengdu Water Supply Company is 1539.27 million yuan.

(6) VFM

$$VFM = \text{PSC} - \text{service payments} \ = 4375.45\text{million yuan.}$$

The VFM $>$ 0, the project should be pursued as a PPP.

42.5 Conclusion

This paper provides the first case study for the practitioners to use value for money to compare the efficiency of the PPP procurement with the traditional procurement during the full life cycle of the project. The Chengdu No. 6 Water Plant B project is a successful PPP project, and it indicates that the PPP mode is applicable in China. Meanwhile, this case also provides a lot of valuable experience for the ongoing PPP projects. For example, it allows for an evaluation of the impacts of the project and the spillover effects that can be expected when private investment is used to provide public utility services. However, the government focus on the service quality of the project, while the private sector focus on the profitability of the project, the credits and solid financial strength of the government. As a result, the risks concerned by the government and private sectors are not always consistent with each other. Thus, this paper provides the foundation and impetus for future work to be undertaken in this fertile and important area for risk allocation between public and private sector.

Acknowledgments Completion of this paper is attributed to the financial support from the National Natural Science Foundation of China (NSFC) under the project No. 71371131.

References

1. Australia I (2008) National public private partnership guidelines, vol 4. Public sector comparator guidance. Infrastructure Australia
2. Chan AP, Lam PT et al (2014) Cross-sectional analysis of critical risk factors for PPP water projects in China. J Infrastruct Syst 21(1):04014,031
3. Chen C (2009) Can the pilot bot project provide a template for future projects? A case study of the chengdu no. 6 water plant B project. Int J Proj Manag 27(6):573–583
4. Chen C, Messner JI (2005) An investigation of Chinese bot projects in water supply: a comparative perspective. Constr Manag Econ 23(9):913–925
5. Hu Z, Chen S, Zhang X (2014) Value for money and its influential factors: an empirical study of ppp projects in Japan. Built Environment Project and Asset Management 4(2):166–179
6. Lee S (2010) Development of public private partnership (ppp) projects in the Chinese water sector. Water Resour Manag 24(9):1925–1945
7. Li X, Liao X et al (2015) Evaluation of work efficiency and medical quality for a hospital on the PPP model in China with benchmarking and GRA. J Grey Syst 27(1):13–26
8. Liu W, Li W, Xu X (2015) The prospect analysis of the PPP financing model application in ports of China. LISS 2014. Springer, Berlin, pp 1183–1189
9. Morallos D, Amekudzi A et al (2009) Value for money analysis in US transportation public-private partnerships. Transp Res Rec: J Transp Res Board 2115:27–36
10. Qi X, Yi C, Li J (2014) The improvement measures of the Chinese PPP project decision-making system compared with Australia. Appl Mech Mater Trans Tech Publ 501:2623–2627
11. Song J, Song D et al (2013) Risk identification for PPP waste-to-energy incineration projects in China. Energy Policy 61:953–962
12. Xu Y, Chan AP et al (2015) Critical risk factors affecting the implementation of PPP waste-to-energy projects in China. Appl Energy 158:403–411
13. Zhang S, Gao Y et al (2015) PPP application in infrastructure development in China: Institutional analysis and implications. Int J Proj Manag 33(3):497–509
14. Zhang Y (2014) From state to market: private participation in China's urban infrastructure sectors, 1992–2008. World Dev 64:473–486

Chapter 43
Multi-sided Market's Performances in the Presence of Network Externality

Jinjiang Yan, Kai Zhu, Lu Huang and JianKai Xing

Abstract With the rapid developments of modern technologies, collaborative economics are warmly welcomed by public. Meanwhile the competitions between collaborative supplier and traditional supplier are getting stronger. Considering the presence of network externality, we study the performances of multi-sided market in which exists both traditional supplier and collaborative supplier characterized by supplying products or services with their idle capacities. Moreover, this paper investigates the conditions under which it would be favorable for collaborative supplier in the competition. And we find that the gap between collaborative supplier's network size and traditional supplier's network size is a determinative factor that decides whether the collaborative supplier can gain an absolute advantage in the competitions or not. In addition, the strength of cross-side network effects exerts positive effects on pricing. And the price of collaborative supplier's products or services can be improved, when the collaborative supplier obtains stronger strength of network externality.

Keywords Multi-sided market · Collaborative economic · Network externality · Pricing

43.1 Introduction

In recent years, collaborative economic (also called sharing economic) has developed greatly. For instances, many customers buy pre-owned goods from others on eBay rather than buy new products from big brands; customers acquire car services via Car2Go rather than own a car; customers get moving help on Task Rabbit rather than hire a moving company; customers have a rest in home through Airbnb rather than stay at hotel; customers borrow from each other through lending club rather than get a loan from a bank and so on. Empirical investigation shows that neo-sharers who

J. Yan · K. Zhu · L. Huang (✉) · J. Xing
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: hl.scu@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_43

have already been using sharing services in the past 12 months constitute 23 % of the population in the US as well as the UK and 25 % of the population in the Canada in 2013 [13]. Otherwise, Nagi and Chau [12] pointed out that people got what they need from others in the sharing economic so that we can protect our environment better, compared with unsustainable pattern of consumptions in industrial economic. So we should make all industrial products sustainable for lower environmental impacts in the production and consumption.

Collaborative consumption is becoming very crucial for businesses more than ever before. It is worth to put more attentions on the research of collaborative consumptions. In this paper, we study a game-theoretical model about competition between collaborative supplier and traditional supplier in the multi-sided market that connects collaborative supplier, traditional supplier with buyers and facilitates the transactions between them. Muzellec [11] showed that multi-sided market as an intermediary brings together two or more sets of agents and characterized by network externality. Hagiu and Wright [8] pointed out that multi-sided platform has two key features: it enables direct interactions between two or more distinct sides and each side is affiliated with the platform. Piscicelli [14] also discovered that consumers' utilities can influence the acceptance, adoption and diffusion of collaborative consumption. And consumers' utilities are mainly affected by network externality in multi-sided market. Some consider market competitions in the presence of network externality, which indicates that the consumer's utility is an increasing function of the number of suppliers in the same platform (multi-sided market is also called multi-sided platform). For instance, consumer obtains greater utilities if the number of the suppliers on the same market increases. Similarly, supplier's utility can be increased when more consumers join in the market. The reasons are that more suitable matches are created by increased numbers of suppliers able to interact with or buyers have more better chooses from increased varieties of products. For instance, if more and more suppliers are willing to join in the shopping mall, the consumer's utility can be improved for more varieties of products that they can choose. Similarly, supplier's utility can be enhanced by increased number of buyers for greater potential transactions. In total, more consumers attract more suppliers, which in turn attract more consumers.

Nintendo Wii leads the game console market. However, Will has two significant disadvantages when it enters the market. One is that Will enters the market later than its competitors (Box360 and PS3). Such later is extremely disadvantageous in the game console market for the presence of network externality. Smaller network size brings fewer utility for customers in the market and has low attractiveness for customers outside the market. Moreover, Allen [1] discovered that low technical level is another point. Wii's graphics and processing capacities substantially fall below the criterions set by its competitors. Box360 and PS3 invest more heavily on platform's technologies than Wii, which further enlarge the technical gap between them. However, the investments on the technologies boosts the production costs of developers and higher price of developers' products reduce the market attractiveness for consumers. Ultimately, much less varieties of products are available to consumer and their utilities are reduced when the network externality exists. In the end, Wii dominates the game console market.

Bakos and Katsmakas [4] considered the network externality as the result of platform investments and indicates that platform sponsors should make the asymmetrical investments on two sides of the market to obtain greater utilities. Mantena and Saha [10] gained the insights that the platform should charges higher price for buyer-side or seller-side for stronger cross-side network effects. Different from the indirect competition between two platforms, we consider direct competition between collaborative suppliers and traditional suppliers in the one multi-sided market.

We also obtain some helpful implications for managers and researchers. Gap between collaborative supplier's network size and traditional supplier's network size is a determinative factor that decides whether collaborative supplier dominates market or not. When collaborative suppliers obtain advantage in obtaining greater network size, they gain greater market shares than traditional suppliers, charge the buyers with higher price and get more profits from the transactions. Furthermore, it is worth subsidizing the buyers who have low expected utilities because of the existence of network externality. In addition, the strength of cross-side network effects exerts positive effects on pricing. And the price of collaborative suppliers' products can be improved, when the collaborative supplier obtains stronger strength of cross-side network effects.

The rest of this paper is organized as follows. In Sect. 43.2, we review related literatures. In Sect. 43.3, we present our game-theoretical model of competition. Conclusions and discussion are presented in Sect. 43.4.

43.2 Literature Review

There exists many researches relative with multi-sided market in recent year and experts as well as scholars mainly study it from investment, network externality, pricing, multihoming, collaborations between competing platforms, subsidy and so on. For instances, Roson [16] and Wright [17] underlined the differences between multi-sided market and nontraditional or one-sided market. And they pointed out that platform can manipulate both the price level (total fees are charged on the customers in the market) and price structure (how the total price is split up). A common strategy for platform sponsors is to subsidize one side of market that has low willingness to join the market.

Some literatures focus on pricing to coordinate the agents, enhance participation and maximize the platform's profits. Rochet JC and Tirole [15] presented two-sided pricing strategies for profit and non-profit platform. Similarly, Armstrong M [3] studied both monopolistic and competing platform and found that pricing structure was mainly affected by strength of network externality, the costs structures and whether the customers were single-home or multihoming. Multihoming is that a customer joins more than one market simultaneously, which lower the price of supplier's products in some industries comparing with the consumer that is single-home.

These studies provided valuable insights on the role of pricing strategies in obtaining demand on customers in the markets.

Litter works have been done to studies the role that technologies play in multisided markets. Despite its importance, the issue has not received commensurate attentions. Among the few exceptions, Eisenmann [6] gave excellent description of how technologies create values in the platform markets and highlighted its importance. Katsamakas and Bakos [4] studied the effect of platform ownership structures' influences (independent, consumer-owned, supplier-owned) on the choice of technology in a monopoly setting. Mantena and Rajib L. Saha [10] researched the opportunities for collaboration between competing platforms with heterogeneous technology level. Similarly, Anderson [2] also studied the role of technology in the platform competition but separate the effect of technology from network externality. However it is not advisable that technology can exerts effects on the magnitude of network effects.

Multi-sided market is characterized by network externality and the customers' utilities can be enhanced or reduced in the presence of network externality. Dai and Kauffman [5] verified that consumers generated the positive effects on the suppliers and negative effects on the other consumers. Bakos and Katsamakas [4] regarded network externality as exogenous factor as the result of platform's investments. And they showed that it was optimal for platform sponsors to make asymmetrical investments on two-sided platform to gain stronger strength of cross-market network effects on one side and high participation on the other side. Moreover, total profits that two-sided platform created were greater from society's perspective and platform obtained the profits all through the customers who have stronger network externality.

Lin [9] studied impacts that buyer-side access fee exerts on seller's utility, taking price competitions and sellers' innovations into consideration. And they presented that buyer-side access fee could exert negative network effects on seller-side equilibrium revenues and the negative network effect was absent when it was bellow the threshold. Andrei [7] studied the strategic use of first-party content by two-sided platform and they showed that it was driven by two key factors: customers' expectations (favorable or unfavorable) and relationship between first-party content and third-party content (complements or substitutes).

43.3 The Model

In order to diminish the product's infinite elasticity of substitution, Hotelling model makes the supplier's products discrepant by incorporating the transportation costs and consumers pay higher transportation costs when the distance between buyer and supplier increases. So the consumers not only consider price of product but also transportation costs. Extending the Hotelling linear city model, we put up our game-theoretical model of competition. In our model there are two sets of suppliers (called collaborative suppliers and traditional suppliers respectively). And we assume that two sets of suppliers enter the market simultaneously, make their choices independently and don't observe competitor's behaviors. Without loss of generality, the agents on the other sides of market are called buyer, and we assume that buyers are single-home, because the products provided by suppliers is homogeneous if we don't consider the transportation costs.

The collaborative suppliers produce the products (or services) through its spare production capacities and we denote the number of transactions between collaborative suppliers and buyers by D_{BC}. While D_{BT} refers to the number of transactions between traditional suppliers and buyers. Moreover, we assume that there are N_C potential collaborative suppliers and N_T potential traditional suppliers in the multi-sided market. The two types of suppliers have the same marginal constant cost to produce the products. Furthermore, there are N_B potential buyers in the market and they have different preference for suppliers, which are modeled as buyers distribute uniformly along a unit interval and the suppliers locate at the opposite end of the interval. The greater distance between buyer and collaborative supplier represents the lesser degrees of preference for collaborative supplier, because the buyer pays higher transportation costs at this situation. Without loss of generality, we assume that collaborative suppliers locate at point zero and traditional suppliers occupy the point one.

Moreover, we denote the transportation cost by parameter t that represents degree of differences between collaborative supplier's product and traditional supplier's product. And lower transportation cost means lesser discrepancies for product and stronger competition. To make the problem simple, we assume that the buyers have adequately high consumer surplus to ensure that buyers all participate in the market and the result is only affected quantitatively, not qualitatively. The frequently used notations are listed in Table 43.1.

According to the assumptions, a buyer's net utilities from transacting with collaborative supplier is given by

$$U_{BC} = \beta N_c - P_C - x \times t. \tag{43.1}$$

Whereas a buyer's net utilities from transacting with traditional suppliers is given by

$$U_{BT} = \beta N_T - P_T - (1 - x) \times t, \tag{43.2}$$

where P_C, P_T refers to the collaborative supplier's price of product and traditional supplier's price of product respectively. And β is the buyer's strength of network externality. x is the distance between the buyer and collaborative supplier. We denote the indifferent buyer who has no difference from transacting with collaborative supplier or traditional supplier by x^*. Through Eqs. (43.1) and (43.2), we get the x^* given by

$$X^* = \frac{[\beta \times (N_C - N_T) + (P_T - P_C) + t]}{2t}. \tag{43.3}$$

Table 43.1 Frequently used notations in the paper

P_C	The price of product that collaborative supplier provides buyer with
P_T	The price of product that traditional supplier provides buyer with
D_{BC}	The number of transactions between collaborative suppliers and buyers
D_{BT}	The number of transactions between traditional suppliers and buyers
π_{BC}	The revenues that collaborative suppliers obtain from the transactions
π_{BT}	The revenues that traditional suppliers gain from the transactions
π	The total profits of platform
C_I	The fixed cost of platform
C	The collaborative supplier's marginal cost
t	The unit of transportation cost
A_C	The collaborative suppliers' access fee charged by the platform
A_T	The traditional suppliers' access fee charged by the platform
β	The strength of network externality about buyers
N_C	The potential numbers of collaborative suppliers in the market
N_T	The potential numbers of traditional suppliers in the market
N_B	The potential numbers of buyers in the market
x	The distances between collaborative suppliers and buyer
U_{BT}	The buyer's net utilities from transacting with the collaborative suppliers
U_{BC}	The buyer's net utilities from transacting with the traditional suppliers

And we find that buyers choose to dealing with collaborative suppliers when buyers' location is on the left side of x^*. Similarly, the buyers whose location is on the right of transact with traditional suppliers. The demands that buyers consume the collaborative suppliers' products are given by

$$D_{BC} \times (P_C, P_T) = x \times N_B. \tag{43.4}$$

Similarly the demands that buyers consume the products produced by traditional suppliers are given by

$$D_{BT} \times (P_C, P_T) = (1 - x) \times N_B. \tag{43.5}$$

According to the previous analysis, we substitute the into Eqs. (43.4) and (43.5). Then we get the number of transactions between traditional suppliers and buyers and number of transactions between collaborative suppliers and buyers respectively.

$$\begin{aligned} D_{BC} \times (P_C, P_T) &= N_B \times \frac{[\beta \times (N_C - N_T) + (P_T - P_C) + t]}{2t}, \\ D_{BT} \times (P_C, P_T) &= N_B \times \frac{t - [\beta \times (N_C - N_T) + (P_T - P_C)]}{2t}. \end{aligned} \tag{43.6}$$

In the market where traditional suppliers and collaborative suppliers give their price simultaneously, buyers all participate in the market for the adequate customer surplus. And we get the revenues of collaborative suppliers by

$$\pi_{BC} = (P_C - C) \times D_{BC} \times (P_C, P_T) - N_C \times A_C. \tag{43.7}$$

Similarly we get traditional suppliers' revenues by

$$\pi_{BT} = (P_T - C) \times D_{BT} \times (P_C, P_T) - N_T \times A_C, \tag{43.8}$$

where A_C, A_T is the access fee charged by the platform and they are constant. The objection of maximizing the profits from the society's perspective is given by

$$\max \pi_I = \pi_{BC} + \pi_{BT} + (N_C \times A_C + N_T \times A_T - C_I). \tag{43.9}$$

Substituting the Eqs. (43.6), (43.7) and (43.8) into the objection in Eq. (43.9), we discover that total profit of market is concave and get the equilibrium outcome as the following:

$$\begin{aligned}
P_C &= \frac{1}{3} \times \beta \times (N_C - N_T) + (t + C), \\
D_{BC} &= \left[\frac{1}{2} + \frac{1}{6t} \times (N_C - N_T) \times \beta\right] \times N_B, \\
\pi_C &= \left[\frac{t}{2} + \frac{\beta}{3} \times (N_C - N_T) + \frac{\beta^2}{18t} \times (N_C - N_T)^2\right] \times N_B, \\
P_T &= -\frac{1}{3} \times (N_C - N_T) + (t + C), \\
\pi_T &= \left[\frac{t}{2} - \frac{1}{3} \times \beta \times (N_C - N_T) + \frac{1}{18t} \times \beta^2 \times (N_C - N_T)^2\right] \times N_B, \\
\pi_I &= N_B \times \left[t + \frac{\beta^2 \times (N_C - N_T)^2}{9t}\right] - C_I.
\end{aligned} \tag{43.10}$$

From the above, we find that collaborative suppliers charge buyers with higher price, gain a greater market shares and revenues, which relies on the key condition that collaborative supplier can obtains a greater network size compared with traditional supplier. In this situation, the collaborative supplier network size is bigger than the traditional supplier network size. Analogically, we can get similar market performances, if the traditional supplier network size surpasses the collaborative supplier network size. From the perspective of society, whoever gets advantage in the network size does not matter, because the total profits relies on the gap between collaborative supplier network size and traditional supplier network size.

However, the collaborative suppliers can get advantages in having lower costs of production and obtaining greater marginal utility, because collaborative suppliers produce their products by their spare production capacities. In addition, collaborative economic is a better way to protect our environment, compared with unsustainable pattern of consumptions in the industrial economic. So we should develop the sharing economic and make some proper measures to help collaborative supplier obtains greater network size. As described previously, in the presence of network externality, when collaborative suppliers obtain greater network size, they can attract more buyers and create greater utilities. So the platform sponsors should make some proper measures to enlarge the gap between collaborative supplier network size and traditional supplier network size.

43.4 Conclusion and Discussion

According to the above analysis, we can draw some valuable implications. We discover that the gap between collaborative supplier network size and traditional supplier network size is a determinative factor that decides whether collaborative supplier dominates market or not. In the presence of externality, greater network size attracts more customers and improves the buyers' utilities. When collaborative supplier gains a greater network size compared with traditional supplier, it obtains competitive advantage in pricing and gains greater market share, collaborative supplier charges buyers with higher price and earns more revenues. And the advantages become more evident when the gap enlarges.

Other notable finding is that network externality not only affects pricing but also magnifies the effects on obtaining the greater market shares. When the buyer's strength of cross-side network effects becomes stronger, the buyers gain more utilities and they would pay more for supplier's products. On the other hands, improved strength of cross-side network effects can magnifies the effects of the gap of network size. And it assists the collaborative supplier obtain more customers, for greater network size is more attractive.

Moreover, subsiding the buyers who have low expected utilities is also rewarding, because the increased revenues from regained lost transactions can compensates the costs. And it is also notable that transportation costs can affects number of transactions too much. Low transportation costs make the collaborative supplier gain enormous market share, because drastic competition is more favorable for collaborative supplier in the presence of network externality.

In this paper, we assume that buyer has enough consumer surpluses so that they all participate in the market. However, in the real world, the scene that buyers are partly priced out is common. So it is more realistic to partition market through two dimensions: consumer's type and distance between buyer and collaborative supplier. In that situation, some buyers having low willingness to purchase do not join the market. Other notable point is that we exclude the negative network externality in the competition. For instance, buyer generates negative network effects on other buyers given a fixed number of suppliers, taking public transport generates fewer utilities for passengers, when the passengers are getting more and more given a fixed suppliers. In the real world, negative network externality caused by competitors is universal and our future researches should pay more attentions on it. Otherwise, if we abstract the transportation costs, the product in our paper is substituted. The complementary products are also very important. And it benefits all customers when different supplier provides complementary products. The substitute and complement simultaneously also should be paid more attentions.

Acknowledgments The philosophy and social sciences planning project of Sichuan province: the research on retail statistics method of electronic commerce (SC14TJ05). The research project of the key research base of humanities and social sciences in universities of Sichuan province: the study on the development mode of O2O e-commerce in liquor making enterprises (CJY15-03).

References

1. Allen D (2006) First look: Sony PS3 versus Nintendo Wii. Available from PC World http://www.pcworld.com/article/127881/article.html
2. Anderson EG, Parker G, Tan B (2014) Platform performance investment in the presence of network externalities. Inf Syst Res 25(1):152–172
3. Armstrong M (2006) Competition in two-sided markets. RAND J Econ 37(3):668–691
4. Bakos Y, Katsamakas E (2008) Design and ownership of two-sided networks: implications for internet platforms. J Manag Inf Syst 25(2):171–202
5. Dai Q, Kauffman RJ (2006) To be or not to B2B: evaluating managerial choices for e-procurement channel adoption. Inf Technol Manag 7(2):109–130
6. Eisenmann TR, Parker G, Van Alstyne MW (2006) Strategies for two-sided markets. Soc Sci Electron Publ 84(10):92–101
7. Hagiu A, Spulber D (2013) First-party content and coordination in two-sided markets. Manag Sci 59(4):933–949
8. Hagiu A, Wright J (2015) Multi-sided platforms. Int J Ind Organ 43:162–174
9. Lin M, Li S, Whinston AB (2011) Innovation and price competition in a two-sided market. J Manag Inf Syst 28(2):171–202
10. Mantena R, Saha RL (2012) Co-opetition between differentiated platforms in two-sided markets. J Manag Inf Syst 29(2):109–139
11. Muzellec L, Ronteau S, Lambkin M (2015) Two-sided internet platforms: a business model lifecycle perspective. Ind Mark Manag 45(1):139–150
12. Ngai E, Chau D et al (2013) Energy and utility management maturity model for sustainable manufacturing process. Int J Prod Econ 146(2):453–464
13. Owyang J, Samuel A, Grenville A (2014) Sharing is the new buying: how to win in the collaborative economy
14. Piscicelli L, Cooper T, Fisher T (2015) The role of values in collaborative consumption: insights from a product-service system for lending and borrowing in the UK. J Clean Prod 97:21–29
15. Rochet J, Tirole J (2003) Platform competition in two-sided markets. J Eur Econ Assoc 1(4):990–1029
16. Roson R (2005) Two-sided markets: a tentative survey. Rev Netw Econ 4(2):142–160
17. Wright J (2004) One-sided logic in two-sided markets. Rev Netw Econ 3(1)

Chapter 44
Application of GA-GMDH Prediction Model in Operational Monitoring of SMEs in Chengdu

Rui Wang, Bingbing Ling and Fuzheng Wang

Abstract Small and medium-sized enterprises are the main part of the regional economy. The development of SMEs aims to stabilize growth, adjust structure, promote reform and enhance the entrepreneurship and innovation. So it's important to research on the operation situation of SMEs for central and local governments. In recent prediction studies of the operational states of SMEs, we find that there are problems of "multicollinearity" and "over-fitting" in large monitoring index system. In the paper, the genetic algorithm was adopted to reduce the dimension of independent variables. After that, the indexes could be used as independent variables of prediction model. Then the prediction model was constructed by the group-method of data handling which had unique superiority in complex system modeling. Finally, we established GA-GMDH prediction system model. The prediction effect of the operation condition of SMEs in Chengdu showed the system model owned high prediction precision and better effect, effectively reduced the association strength between independent variables.

Keywords Small and medium-sized enterprises · Operational monitoring · Prediction · Group-method of data handling · Genetic algorithm

44.1 Introduction

In order to master the development situation of SMEs and formulate the accurate support policies, Ministry of Industry and Information Technology (MIIT) required each province to establish operation monitoring platform for SMEs and operated it in January 2012. By 2015, more than 5000 small and medium-sized and micro enterprises in Sichuan had built monitoring platform.

The research work on prediction model of operation condition of SMEs had been carried out since the operation monitoring platform was launched. Wang et al. [1]

R. Wang · B. Ling (✉) · F. Wang
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 840200828@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_44

had built an interval forecasting model for monitoring indicators of small and micro enterprises. Shen [2] established a system model to effective early warn the operating status about SMEs in Sichuan province. Peng et al. [3] presented a group method of the symmetric triangular fuzzy numbers to analyze the small and micro enterprises in Sichuan Province.

However, these studies also showed the problems of "over-fitting" and "multi-collinearity". We can see the operation monitoring index system is relatively large and there is larger correlation between the indicators. To solve the problems, we need to reduce the association strength between independent variables.

The common dimension reduction methods include multiple regression and correlation analysis, principal component analysis, genetic algorithm and so on [4–7]. These methods can be roughly summed up in two categories: multivariate statistical analysis method and evolutionary algorithm. Due to the main problem in prediction model for SMEs is so many indexes and the larger correlation between variables, it is difficult to quickly get the set of independent variables with low correlation only through the conventional multivariate statistical analysis method. Thus, genetic algorithm (GA) is a better choice.

After appropriate screening of independent variables, there are still too many independent variables. In addition, the application of conventional multivariate statistical analysis method shows long time and low efficiency. Therefore, GMDH is a kind of more convenient and efficient method we can utilize.

44.2 Using GA to Reduce the Dimension of Independent Variables

44.2.1 Indicator Variables

According to the data we can obtain, the monitoring indicators are divided into two categories: monitoring indicators of production and operation and the operator confidence survey indexes, five grades of comments including excellent, good, general, relative poor and poor. Specific indexes and the corresponding variables are shown in Table 44.1.

44.2.2 Fitness Function

In the genetic algorithm, the process of simulating natural selection is realized by fitness function. It calculates the fitness of each individual relative to the whole. Individuals with high fitness are more likely to be copied to the next generation than individuals with low fitness.

Table 44.1 Operational monitoring indicators and operator confidence survey indexes

Variable	Operational monitoring indicators	Variable	Operator confidence survey indexes
X_1	Number of enterprises	X_{23}	Overall production and operation of enterprises (This month)
X_2	Number of loss-making enterprises	X_{24}	Overall production and operation of enterprises (Next month)
X_3	Losses	X_{25}	Overall operation of the industry (This month)
X_4	Deficits	X_{26}	Overall operation of the industry (Next month)
X_5	Gross value of industrial output	X_{27}	Recruiting numbers this month
X_6	Export delivery value	X_{28}	Domestic market orders
X_7	The use of electricity	X_{29}	Export orders
X_8	Capacity Utilization	X_{30}	Enterprise working capital
X_9	Operating income	X_{31}	Ability to meet the financing needs of the enterprise
X_{10}	Operating costs	X_{32}	Recent fluctuation of raw material purchased price
X_{11}	Ending loan balance	X_{33}	Recent fluctuation of energy purchased price
X_{12}	Financing expense	X_{34}	Raw materials whether meet the needs
X_{13}	Receivables	X_{35}	The impact of rising labor costs
X_{14}	Finished products	X_{36}	The fitting of managerial talents
X_{15}	Total profits	X_{37}	The fitting of professionals
X_{16}	Taxes payable	X_{38}	The solvency of its loans
X_{17}	Household employees	X_{39}	Ability to meet the productive land needs
X_{18}	Employee	X_{40}	The implementation of policies
X_{19}	Staff salaries		
X_{20}	Total assets		
X_{21}	Total indebtedness		
X_{22}	Fixed investment		

In this paper, we improve the fitness function. Calculate the Pearson correlation coefficient for each pair of variables in the sample. Then add up their absolute values, the sum value is association strength. The fitness function corresponding to the chromosome is obtained by taking the reciprocal of association strength. Thus,

$$\rho_{X_i,X_j} = \frac{\mathrm{cov}(X_i, X_j)}{\sigma_{X_i}\sigma_{X_j}} = \frac{E[(X_i - \mu_{X_i})(X_j - \mu_{X_j})]}{\sigma_{X_i}\sigma_{X_j}}, \tag{44.1}$$

where $\mathrm{cov}(X_i, X_j)$ is the covariance of X_i and X_j; ρ_{X_i,X_j} is the Pearson correlation coefficient of X_i and X_j, $\rho_{X_i,X_j} \in [-1, 1]$.

We define the fitness function as

$$\mathrm{Fit}(X) = \frac{1}{\sum |\rho_{X_i,X_j}|}, \tag{44.2}$$

where $\rho_{X_i,X_j}|$ is the association strength, X_i, X_j are indicator variables in Table 44.1.

44.2.3 GA Dimension Reduction

Utilize genetic algorithm to reduce the dimension of independent variables, the process is shown as follows:

(1) Initialization: the algorithm automatically generates an initial population;
(2) Individual evaluation: calculate the fitness value of each chromosome in the initial population through the Eq. (44.2);
(3) Selection: according to the size of the fitness value of each chromosome, we can decide chromosomes which can be inherited to the next generation, which are directly eliminated;
(4) Crossover: utilize the single-point crossover operator to reduce dimension. Make the individuals pairwise; for each pair, selecting a locus as the cross dot randomly; for each pair, producing two new individuals based on changing the location of cross dot. The diagrammatic map is shown in Fig. 44.1.
(5) Mutation: utilize the single-point mutation operator to reduce dimension. Generate the mutation point randomly; change the locus according to the location of mutation point. Result of the operation is “1” to “0” or “0” to “1”. The diagrammatic map is shown in Fig. 44.2. After selection, crossover and mutation of the initial population, it will produce a new generation;

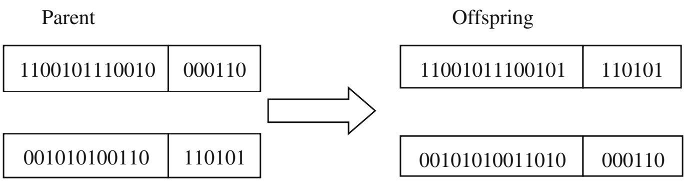


Fig. 44.1 Diagrammatic map of single-point crossover

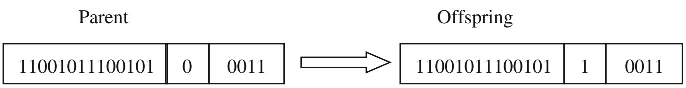


Fig. 44.2 Diagrammatic map of single-point mutation

(6) Termination condition judgment: if the optimal fitness of chromosomes is the optimal solution of problem, then the model program is terminated.

44.3 Utilize GMDH to Predict

44.3.1 GMDH Prediction Theory

The emergence and development of GMDH is based on neural network and the rapid development of computer science [8]. The main idea is that produce the first generation of intermediate candidate models through a variety of initial inputs by using cross-link. Select the best combination from the intermediate models of first generation to generate the second, repeat this process in order to increase the model complexity until finding the optimal model [9].

Most models in the economic forecasting are dynamic models and the lagging structure of the equation will influence on the properties of model. The 38 variables in this paper are economic variables, many are not only affected by the same period factors, but also related to the previous value, which belong to the lagging variables. When predicting the lagging variables, the GMDH model is used to determine the optimal dynamic structure and the optimal lagging number. It can improve the accuracy of prediction when applied to the complex system.

44.3.2 GMDH Prediction Algorithm

Main idea: in small sample system, produce many initial models according to the K-G polynomials, then select an optimal prediction model from initial models on the basis of external criterion, the specific prediction process is indicated below:

Firstly, let Z be the sample data set which collected for modeling; secondly, let the sample data N be divided into a training set A and a testing set B, and then,

$$N_A + N_B = N_Z, \qquad Y = A \cup B.$$

Utilize the K-G polynomials to establish the function of dependent variables and independent variables, that is

$$y = a_0 + \sum_{k1} a_{k1} x_{k1} + \sum_{k2} \sum_{k1} a_{k1,k2} x_{k1} x_{k2} + \sum_{k3} \sum_{k2} \sum_{k1} a_{k1,k2,k3} x_{k1} x_{k2} x_{k3} + \cdots .$$

Choose the criterion of minimum deviation to select optimal model, we have

$$[f(x)]^2 = \sum_{teN_A \cup N_B} (f(x_t) - f_t^m(A))^2 \longrightarrow \min,$$

where $f_t^m(A)$ represents an estimate set of the output model in N_A.

Next, generate the first layer equation: each of the n variables is given a model of deterministic differential form.

$$X_i^t = a_0 + \sum_{k=1}^{m} \sum_{j=1}^{\alpha} a_{ik} X_k^{t-j} + \sum_{j=1}^{\alpha} X_i^{t-j} \quad (i = 1, 2, \ldots, n) \tag{44.3}$$

α–Lagging Number; a_{ik}, b_i–Coefficient

Select the input variables for second layer from intermediate models of first layer according to the criterion.

Repeat the above two procedures so that we can get intermediate models of second and third layer, we'll find the optimal model finally.

44.4 GA-GMDH Prediction Model

GA-GMDH prediction model is the combination of genetic algorithm and GMDH model. Firstly, use GA to reduce dimension of independent variables and remove some "redundant" variables, then make the remainder variables as input variables for GMDH prediction.

Algorithm steps are shown as follows:

Step 1. Produce N initial bit strings randomly, each bit string is an individual and the population is formed by the N individuals. Then the algorithm begins to iterate.

Step 2. Calculate the absolute value of Pearson correlation coefficient for each group, then add them up and make the reciprocal of the sum value as fitness function.

$$\mathrm{Fit}(X) = \frac{1}{\sum |\rho_{X_i, X_j}|}, \tag{44.4}$$

where ρ_{X_i, X_j} is the Pearson correlation coefficient for each pair of variables.

Step 3. Select proportion operator and calculate the fitness of population.

$$F = \sum_{k=1}^{n_p} Fit(X_k). \tag{44.5}$$

Calculate the relative fitness of each individual and make it be the probability of inheritance, that is

$$p_k = \frac{f(X_k)}{F}, \quad k = 1, 2, \ldots, n. \tag{44.6}$$

Generate the random number between 0 and 1 by using a "roulette wheel" selection.

Step 4. Utilize the single-point crossover operator to reduce dimension.
Step 5. Utilize the single-point mutation operator to reduce dimension.
Step 6. Through the iterations, we'll find the most representative input variables.
Step 7. Extract the data corresponds to the input variables to analysis the results through using GMDH model. The specific flow chart is shown in Fig. 44.3.

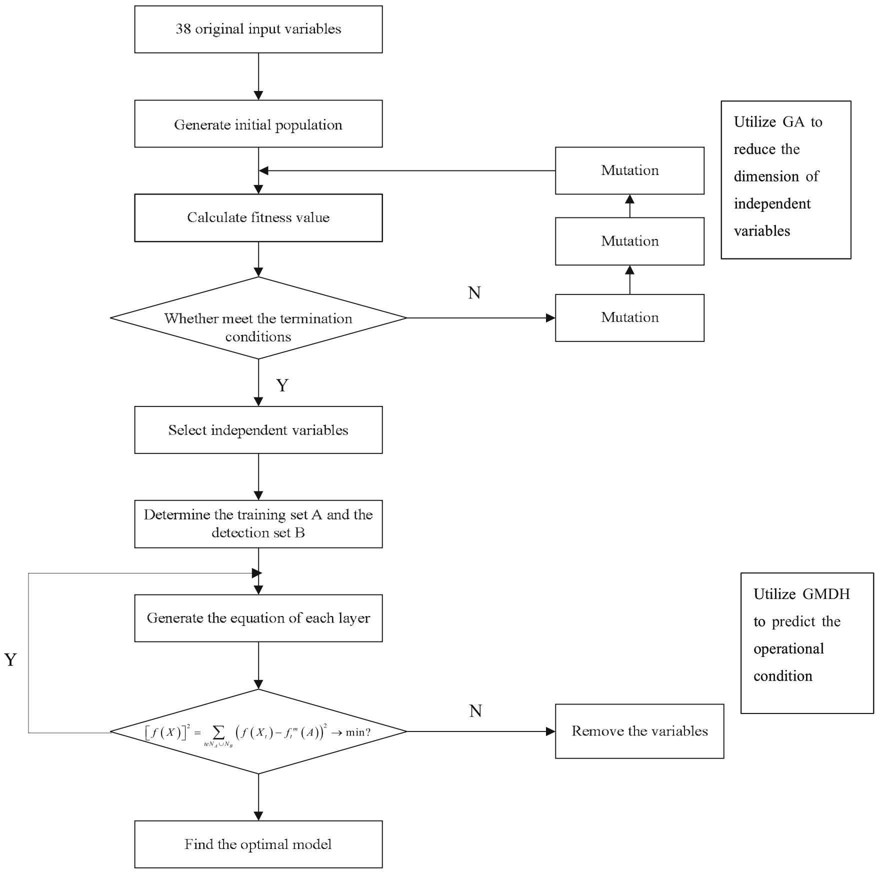


Fig. 44.3 Flow chart of GA-GMDH prediction model

44.5 Empirical Analysis

The history data from January to December in 2014 based on the SMEs of Chengdu was collected and calculated by investigating. Make operating income and total profits as output variables and the others as inputs. Assume the data from January to June is the testing set A and the data from July to December is the training set B. Exploit the Knowledge Miner 5.0 to model, we'll gain the functions and lagging numbers.

44.5.1 Results of GMDH Prediction Model

(1) Prediction model for operating income
Utilize the Knowledge Miner 5.0 to model, we can get

$$\begin{aligned}Y =& -3346.843750 - 13.510506X_{35}^{t-1} + 102.206329X_{29}^{t-1} - 9.433044X_{28}^{t-3}\\&+ 0.125752X_{14}^{t-2} + 23.820005X_{34}^{t-2} - 4.238345X_{30}^{t-1} - 40.403275X_{40}^{t-3}\\&- 0.831168X_{4}^{t-1} - 1.23958X_{10}^{t-1}.\end{aligned}$$

The corresponding indicators for each variable are shown in Table 44.1; superscript represents the lagging number; Y represents operating income.

(2) Prediction model for total profits
Utilize the Knowledge Miner 5.0 to model, we can get

$$\begin{aligned}Y =& -579.759949 + 7.328455X_{8}^{t-3} + 1.586489X_{40}^{t-2} + 1.00869X_{26}^{t-1} + 2.399027X_{35}^{t-2}\\&+ 11.185966X_{29}^{t-1} - 0.775626X_{3}^{t-1} + 0.44085X_{6}^{t-2} + 0.126072X_{10}^{t-1}\\&- 2.133309X_{38}^{t-2} - 0.576952X_{3}^{t-2}.\end{aligned}$$

The corresponding indicators for each variable are shown in Table 44.1; superscript represents the lagging number; Y represents total profits.

44.5.2 Results of GA-GMDH Prediction Model

According to the above procedures, we reduce dimension by genetic algorithm, the final result conducted by matlab is: 1, 2, 3, 5, 6, 10, 12, 13, 17, 20, 22, 23, 25, 28, 31, 35, 40. We can also find the corresponding variables in Table 44.1. Let them be inputs, we'll obtain the functions and lagging numbers.

(1) Prediction model for operating income
The function is

$$Y = 3322.86455 + 40.081387X_{19}^{t-1} - 0.824546X_{4}^{t-1} - 1.229705X_{7}^{t-2} + 1.651328X_{5}^{t-1} + 52.321432X_{16}^{t-1}.$$

The corresponding indicators for each variable are shown in Table 44.1; superscript represents the lagging number; Y represents operating income.

(2) Prediction model for total profits
The function is

$$Y = -58.734062 + 0.16377X_{6}^{t-1} + 1.360965X_{16}^{t-1} - 3.613338X_{19}^{t-2} + 4.484931X_{18}^{t-2} - 0.018964X_{8}^{t-2} - 0.849808X_{2}^{t-1} + 0.143935X_{7}^{t-1} - 0.042879X_{5}^{t-2}$$

The corresponding indicators for each variable are shown in Table 44.1; superscript represents the lagging number; Y represents total profits.

44.5.3 Comparative Analysis of Two Models

Through forecasting the operating income and total profits by GMDH model and GA-GMDH model, we can obtain their predictions of SMEs in Chengdu from January to December, 2014. Compared the prediction accuracy of two models, the results are shown as below.

Thus, we can also get the error comparison chart of the two models (Fig. 44.4 and Table 44.2).

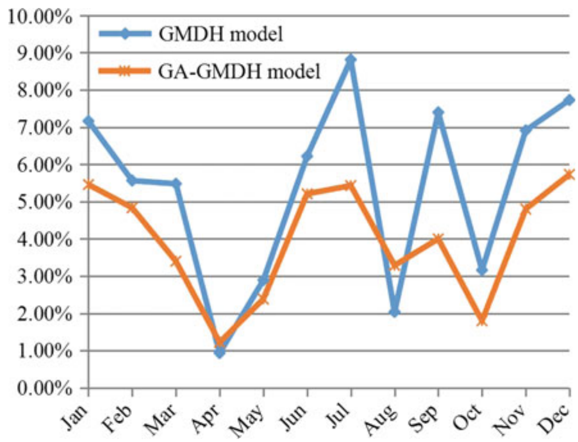


Fig. 44.4 Error comparison chart for operating income

Table 44.2 Comparison of two models on operating income (Unit: 10,000 RMB)

Month	Actual value	Predictive value		Error (%)		Association strength	
		GMDH model	GA-GMDH model	GMDH model	GA-GMDH model	GMDH model	GA-GMDH model
January	877.7778	870.6132	872.3215	7.1646	5.4563		
February	3077.778	3072.2135	3072.9432	5.5643	4.8348		
March	5786.944	5781.4654	5783.5432	5.479	3.4008		
April	7860.278	7859.3461	7859.0562	0.9317	1.2218		
May	9141.437	9138.5431	9139.0532	2.8941	2.3838	9.256	2.738
June	11034.86	11028.64	11029.65	6.2183	5.21		
July	11880.13	11871.32	11874.7	8.8138	5.43		
August	12734.61	12736.65	12737.9	2.0385	3.29		
September	13767.7	13760.3	13763.7	7.3997	4		
October	15648.48	15645.32	15646.68	3.1626	1.8		
November	15157.45	15150.54	15152.65	6.9127	4.8		
December	14308.05	14300.32	14302.32	7.7303	5.73		

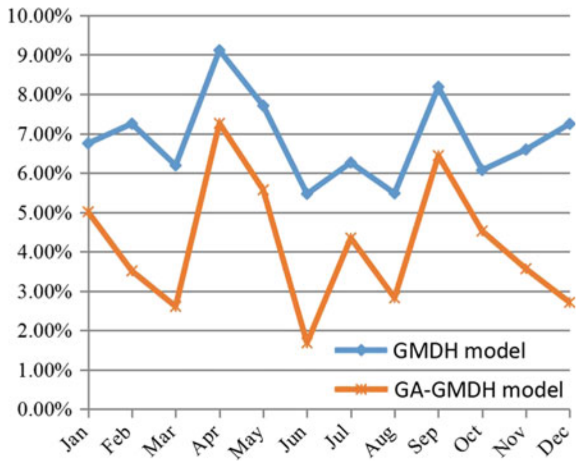
Table 44.3 Comparison of two models on total profits (Unit: 10,000 RMB)

Month	Actual value	Predictive value		Error (%)		Association strength	
		GMDH model	GA-GMDH model	GMDH model	GA-GMDH model	GMDH model	GA-GMDH model
January	8.333333	1.585862	3.321514	6.747471	5.011819		
February	143.0556	135.8095	139.5452	7.246	3.5104		
March	341.3889	335.1996	338.7812	6.1893	2.6077		
April	496.3889	487.2734	489.1278	9.1155	7.2611		
May	544.6981	536.9924	539.1278	7.7057	5.5703	11.689	5.296
June	686.3647	680.0897	688.0457	5.4674	1.681		
July	743.0576	736.7954	738.7108	6.2622	4.3468		
August	797.5353	792.054	794.7104	5.4813	2.8249		
September	865.9176	857.7313	859.4781	8.1863	6.4395		
October	1029.975	1023.904	1025.45	6.0703	4.525		
November	1033.297	1026.704	1029.731	6.5928	3.566		
December	1042.46	1035.21	1039.75	7.2461	2.71		

As shown in Table 44.3, we can get the comparison of two models on total profits. The comparison of prediction error about total profits will be shown in Fig. 44.5.

Thus we can see that the errors of operating income and total profits based on GA-GMDH model are obviously smaller than GMDH model. And the association strength based on GA-GMDH is decreased greatly. Therefore, GA-GMDH

Fig. 44.5 Error comparison chart for operating income



model owns better prediction accuracy and effectively reduce the association strength between independent variables when applied on operational monitoring of SMEs in Chengdu.

44.6 Conclusions

Compared with GMDH prediction model, the GA-GMDH prediction model is much better in prediction of small sample and complex system. We find that GA-GMDH model not only can improve the running speed, but also improve the accuracy of the model to a certain extent. It owns high precision and better effect, effectively reduce the association strength between the independent variable indexes.

The empirical analysis of SMEs in Chengdu demonstrates the effectiveness of GA-GMDH prediction model and we can also get the lagging number of variables, the problems of "multicollinearity" and "over-fitting" are solved well. So this approach can be used in practice possibly. Therefore, we may select GA-GMDH prediction model to forecast the operation situation of SMEs in Chengdu. Due to the better prediction accuracy of GA-GMDH model, the relevant governments and corporate managements can make appropriate policies based on the results of it. Then promote the development of SMEs in Chengdu preferably.

References

1. Wang R, Zhao S, Peng T (2014) Interval forecasting model with arima for monitoring indicators of small and micro enterprises in sichuan province. In: Proceedings of the eighth international conference on management science and engineering management. Springer, Heidelberg, pp 175–186
2. Wang R, Shen Y et al (2014) Operation monitoring system model of small and medium-sized enterprises in sichuan province in 2012. In: Proceedings of the seventh international conference on management science and engineering management. Springer, Heidelberg, pp 357–368
3. Wang R, Peng T, Li Xf (2014) A group method of symmetric triangular fuzzy numbers handling and its application to analyze monitoring data of small and micro enterprises in Sichuan province. In: 2014 international conference on management science & engineering (ICMSE). IEEE, New York, pp 244–250
4. Dong Y, Yu Z, Zhu L (2015) Robust inverse regression for dimension reduction. J Multivar Anal 134:71–81
5. Chen X, Cook RD, Zou C (2015) Diagnostic studies in sufficient dimension reduction. Biometrika 102(3):545–558
6. Sheng W, Yin X (2015) Sufficient dimension reduction via distance covariance. J Comput Graph Stat (just-accepted)
7. Chorin AJ, Lu F (2015) Discrete approach to stochastic parametrization and dimension reduction in nonlinear dynamics. Proc Natl Acad Sci 112(32):9804–9809
8. Mueller JA, Lemke F (2000) Self-organising data mining: an intelligent approach to extract knowledge from data. Pub Libri, Hamburg
9. Harrison P, Stevens CF (1971) A bayesian approach to short-term forecasting. Oper Res Q 22:341–362

Chapter 45
A Study on the Real Estate Price Forecast Model in the Midwest of China–Based on Provincial Panel Data Analysis

Hongchang Mei and Hao Fang

Abstract There are a lot of factors that affect the price of commercial house, which is both the demand and supply factors. Based on the analysis of the variable factors of commercial housing price, the average selling price of commercial housing from 2005 to 2014 in the Midwest of China is used as the primary time data series, and the dynamic state forecasting model of the average selling price of commercial housing in the Midwest is established by using multiple regression analysis and trend analysis method. From the results of the model predictions, the commodity residential sales prices in most provinces of the central and western remain upward trend, some remain stable trend, as there is a small number of them are declining trend. Through the judgment of the price trend in the central and western provinces, in favor of individuals and enterprises to invest in the future, in favor of government regulation reasonable prices, and promote the healthy development of the housing industry.

Keywords Supply and demand theory · Commercial housing · Prices · Prediction model

45.1 Introduction

China's real estate market has experienced ten years of rapid development, which has been in a rising trend. The current urbanization is still in a steady progress, coupled with the improvement of people's living standards improve the demand for housing, which has become a reason to continue to look good real estate. However, with the economic growth into the medium speed range from the high speed, the economic growth rate declined from the previous two to 7 % digits, the economic downturn led to gradually decline in real estate. Because of the their resources and new urban transformation, there are still a lot of potential demand is not satisfied in

H. Mei (✉) · H. Fang
Management School, Chongqing Technology and Business University,
Chongqing 600000, People's Republic of China
e-mail: 1012288379@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_45

the big city, while small and medium-sized inland city have faced large developers disinvestment in many places, their real estate market have also been in trouble, and even the phenomenon of excess housing supply.

Small and medium-sized city in China is mostly distributed in the central and western regions, facing large enterprises evacuation crisis. In 2015 the country introduced the "along the way" policy, which will give the central and western regions along the city to bring new investment opportunities, whether it will stimulate the region's housing prices? In addition, China's current stock market volatility is very large, obviously not a stable investment direction. However, in the face of the central bank to reduce interest rates, the savings is clearly not a wise choice for small and medium-sized cities. How should they keep wealth does not shrink? Therefore, based on these considerations, through the supply and demand theory in the market economy to analyze the factors affecting the real estate prices in the Midwest, to build a forecast model for future housing prices in our country. The purpose is to forecast the future real estate prices in the Midwest of China, hoping for government decision-making, real estate development and investment, personal consumption to provide some useful ideas, suggestions and methods.

This paper mainly divides into six parts, the first part mainly introduces the background and practical significance of the research. The second part mainly summarizes domestic and foreign theoretical literature and related forecasting methods; the third part is mainly based on market supply and demand theory, analyzes the main factors affecting the price of commercial housing in China, and the fourth part is mainly to carry out empirical research. The sixth part mainly summarizes and discusses the results of the research.

45.2 Literature Review

45.2.1 The Literature on Factors Affecting Real Estate Prices

From the perspective of equilibrium theory, most economists believe that real estate supply and demand determine the real estate prices, the main factor in real estate prices rising is supply and demand imbalance. Decaro [3] pointed out that the causes of real estate market fluctuations in supply and demand, the vacancy rate, monetary policy, employment level, population structure and trends. Choy [2] using the feature model to find the size of residential property, the higher the floor, the better the viewing angle, the higher the price of housing, while the location of the metro will make a larger premium. Different from the above theory, Johansen [5] argued that the market demand and the building materials are not the determining factor, the expected price is the determining factor prices, which provides the theoretical basis for the later option pricing model.

Domestic scholars generally believe that the housing price is determined by market supply and demand, but some scholars believe that due to the inelastic supply of real estate in the short term, so the demand is the major determinant of housing prices. Yao and Huang [12] studied "the relationship between land and housing prices", they think the premium associated with housing prices, but non-linear relationship, even if land prices, house prices are not necessarily risen. Other costs were tested only Rigid no decline in space, and developers have to unprofitable point, rise in land prices will be fully reflected in the price, the direct cause of rising house prices. Existing housing prices depend on the ability of existing residents pay demand, prices rose mainly due to the demand-driven rather than cost-driven. Zhang and Zhou [13] thought that with the change of the purchase subject, buying motives, needs and values change in function, the impact of changes in customer demand, changes in customer demand affect property values, causing price changes. Degree of realization of real estate value and customer awareness of the value of real estate as well as market supply and demand related. Deng and Li [4] through gray prediction method, the surface of investment demand price fluctuations than the consumer demand for a stronger explanatory power, while the psychological expectations, buyers down payment policy relative to other factors greater impact on prices.

45.2.2 The Literature on Forecasting Methods of Real Estate Prices

Two basic methods in analysis of the use of foreign scholars on urban housing prices hedonic price methodology and repeat-sale methodology. Changes in prices abroad more in-depth analysis, such as Malpezzi [9] for the price-earnings ratio and price changes obtained by the error correction model the previous price and income changes and short-term effects for the price elasticity of supply weak conclusion. Seko [10] believed that the price of housing and economic fundamentals in Japan each region has a strong correlation. He used the time series model predicting the housing prices selected key indicators include privately owned residential average selling price, household income, population, residential construction area, the consumer price index and the vacancy rate. Anglin [1] introduced the average house price growth rate of lag three period and CPI, mortgage rates and unemployment rates, VAR model, to predict many rounds Rate changes.

Domestic scholars on housing prices more, mostly using linear regression, principal component analysis and long-term trends and other methods to study the factors affecting the housing price and the change process. Zhang and Yang [14] established the benchmark land price forecasting model based on BP neural network. Li and Ma [6] used the gray system GM (1, 1) model to predict the real estate prices. Yan [11] selected macroeconomic, financial and other nine categories of indicators to propose the price forecasting model based on TEI@I method. Liu and Wang [7] applied multiple factors regression, state space model and Kalman filter to predict the trend of real estate prices in China. Ma and Liu [8] built DSGE model to reflect the relationship between real estate price fluctuations and monetary policy regulation.

In summary, the existing literature when analyzing factors affecting the price of the real estate market are mostly from a macro perspective to study the relationship between price fluctuations and the fundamentals, and not in-depth study of the impact of fluctuations in the price of various regions, and no specific analysis of the scope of the price change, but the impact of the factors that affect the price fluctuations will bring much impact. However, in the context of China's economy into the new normal, the fluctuations in the real estate specific price range forecast is particularly important, but no longer limited to the analysis of influencing factors. Based on this, we use a simple and practicable forecasting model—multiple regression analysis to explore the main factors affecting prices according to supply and demand in the market economy principle, and regression analysis and trend analysis of these factors to predict the central and western provinces of real estate future price movements.

45.3 Theoretical Foundation

In the market mechanism, urban residential real estate prices are mainly determined by the supply and demand of residential, but is the result of urban housing production and related socio-economic factors working together. According to available literature data relating to real estate, this paper according to the real estate demand and supply two perspectives, form Table 45.1. List factors affecting the real estate prices.

Table 45.1 List of factors affecting real estate prices

Level indicators	Secondary indicators	Three indicators
Housing demand	Early economic situation	GDP growth
		Budget expenditure
		Financial and tax revenue
	Future changes in value	Year RMB deposit interest rate
		Year RMB lending rate
		Shanghai composite index
	The current capacity to pay	Number of urban population
		Urban residents per capita disposable income
Housing supply	Volume and price level	Commercial housing development investment
		Average selling price of commercial housing
		Commercial housing new construction area
		Commercial housing sales area
		Commercial housing vacancy rate

(continued)

Table 45.1 (continued)

Level indicators	Secondary indicators	Three indicators
	Construction costs	Cement prices
		Steel prices
		Building materials purchase price index
	Other factors	Policy factors
		Social customs

Note GDP represents GDP growth, POPUL represents Number of urban population, PCDI represents Urban residents per capita disposable income, INVEST represents Commercial housing development investment, ASP represents Average selling price of commercial housing, NCA represents Commercial housing new construction area

Taking into account the availability of relevant data, the data can be quantified and missing data for some variables in a given year, so we choose GDP, POPUL, PCDI, INVEST, NCA as explanatory variables in the regression model, select ASP as a regression model explanatory variables.

45.4 Research Methods

This article does not select the VAR model, gray system GM (1, 1) model or BP neural network models and other complex model, but choose a more simple and practical multivariate regression model. Multivariate linear regression analysis is assumed to be linear relationship between the dependent variable and the independent variable, using the mathematical statistics method to construct the empirical formula of the variables and to determine model parameters. The model is considered to be the following three reasons: first, to find the appropriate mathematical expression between variables and the explanatory variables. Second, to determine the influence coefficient of the explanatory variables to the explanatory variables. Third, according to the numerical value of multiple explanatory variables to predict or control the numerical value of the variable. Before making regression analysis, in order to simplify the problem, we have the full regression model, without using stepwise regression analysis on the price of each factor screening and contribution of each factor regression significance for inspection, that we consider only whether the overall linear regression equation significantly. Therefore, we need to make some assumptions:

(1) No major change in policy towards the country's future real estate industry or macro-control measures.
(2) ASP can reflect the average price level of real estate in the provinces.
(3) We only consider five factors above influence on prices, other factors are negligible.

(4) Among these five factors affect the price independent of each other, between two unrelated.
(5) Between the factors and the rate is linear relationship.

45.4.1 Research Object

According to China's administrative division, our country has been divided into three regions in eastern, central and western. Eastern China including Beijing, Tianjin, Shanghai, Liaoning, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, Hainan. Central China including Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan. West China including Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Ningxia, Qinghai, Xinjiang, Inner Mongolia, Tibet.

The main object of this study is the central and western provinces 2005–2014 years of commodity price levels of residential houses, and the data comes from the EPS database, the Chinese Statistical Yearbook and the statistical yearbook of the provinces. According to literature data indicate that reflect the level of real estate prices, usually commercial housing sales price index or commodity residential average selling price (sales of commercial residential / commercial residential sales area), commercial housing sales price index is a comprehensive reflection of the overall level of residential commodity prices changes and changes in the relative number of changes. In this paper, commodity residential average selling price is interpreted as the dependent variable, more intuitive to show the level of housing prices, more conducive to individual and corporate investment decisions.

45.4.2 Data Description

(1) Comparison of the Regional GDP in China

As shown in Fig. 45.1, the eastern GDP gross domestic product has maintained a rapid growth, and probably will leap to a higher level every four years, to new heights. At the same time, GDP in central and western China's GDP has been lagging behind

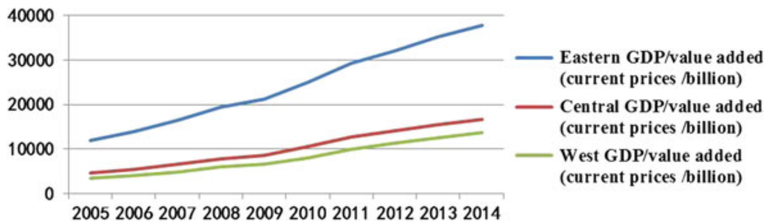


Fig. 45.1 Comparison of the regional GDP in China

in the eastern region, and around the eastern half of the total, Midwest GDP growth gradually narrowing the gap.

(2) Comparison of the Number of the Regional Urban Population in China

As shown in Fig. 45.2, due to the rapid economic development in Eastern China, the location and number of the urban population is more than the Midwest. Central and Western China due to economic development is lagging behind, a relatively small number of urban population, while in western China because of geographical reasons, the total urban population of the west less than the east.

(3) Comparison of the Regional Per Capita Disposable Income in China

As shown in Fig. 45.3, the provinces per capita disposable income radiate upward trend, but the gap between the eastern and mid-western per capita disposable income is gradually widening, people in western and central part of the gap in per capita disposable income decreases, and the per capita disposable income in the East is slightly higher than the midwest.

(4) Comparison of the Regional Residential Real Estate Investment in China

As shown in Fig. 45.4, our country from 2009, the real estate yield residential investment showed a rising trend in the provinces. Because of the advantages of its geographical location and area, the real estate investment in East has maintained rapid growth. Property investment growth rate in the central and western more gentle, the central provinces where the average residential investment more than the west, which may be due to the central flat, relatively dense population.

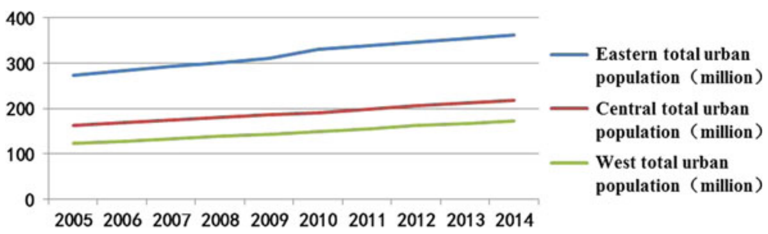


Fig. 45.2 Comparison of the number of the regional urban population in China

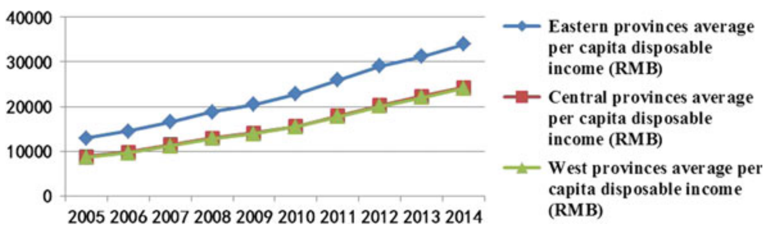


Fig. 45.3 Comparison of the regional per capita disposable income in China

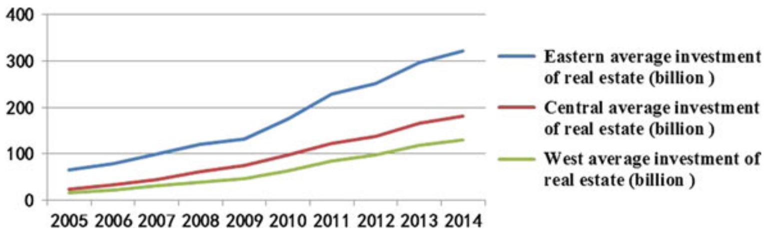


Fig. 45.4 Comparison of the regional residential real estate investment in China

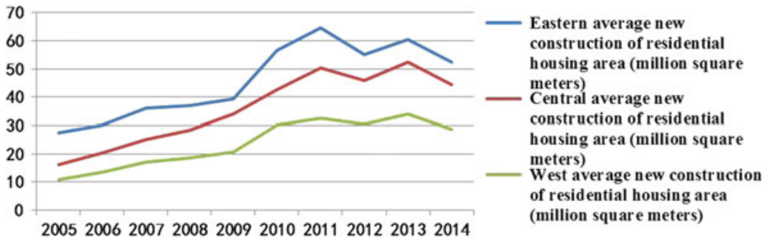


Fig. 45.5 Comparison of the regional newly started residential housing area

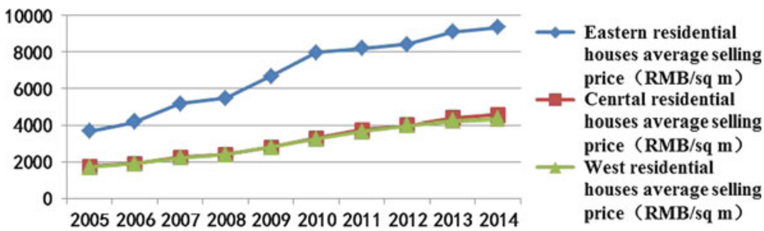


Fig. 45.6 Comparison of the regional average selling price of residential houses in China

(5) Comparison of the Regional Newly Started Residential Housing Area

As shown in Fig. 45.5, the new construction of residential houses of each region from 2005 to 2008 has maintained steady growth, from 2009 to 2011 residential houses spurt of growth, and peaked in 2011, after 2011 new houses the area began to reduce. Particularly, in 2014 the new construction of residential housing area significantly reduced trend. Overall, China's new residential housing area due to the impact of national policies, the emergence of growth trajectory fluctuations style.

(6) Comparison of the Regional Average Selling Price of Residential Houses in China

As shown in Fig. 45.6, prices in eastern China is almost twice around the Midwest, which may be related to the degree of economic development in the east, population density, geographical and other factors. West and central regions Rate has been synchronized growth trend, and housing prices in these two regions remain flat state.

45.4.3 Data Measurement

In this paper, the regression equation was constructed as follows multiple regression model based on the content and assumptions discussed above: $\text{ASP} = \beta_0 + \beta_1 GDP + \beta_2 POPUL + \beta_3 \text{PCDI} + \beta_4 \text{INVEST} + \beta_5 NCA + \mu$. Among them, the variable ASP is interpreted to represent the average selling price of commercial housing, the explanatory variables GDP represents GDP growth, POPUL represents the number of urban population, PCDI represents the per capita disposable income of urban residents, INVEST represents the development of commercial housing investment, NCA represents Commercial housing new construction area. In this paper, EVIEWS8.0 software is used to analyze the model, according to Table 45.2 to determine the overall value of the linear regression equation of the relationship is significant.

Table 45.2 Regression significance of housing prices in the midwest of China

	R^2	adjR^2	F	P	DW	Significant
Shanxi	0.99	0.98	73.96	0	2.23	TRUE
Jilin	0.97	0.94	30.53	0	1.63	TRUE
Heilongjiang	0.99	0.98	91.08	0	2.82	TRUE
Anhui	0.99	0.98	89.94	0	2.53	TRUE
Jiangxi	1	0.99	247.42	0	3.23	TRUE
Henan	1	0.99	261.76	0	2.31	TRUE
Hubei	0.99	0.97	65.45	0	2.93	TRUE
Hunan	0.99	0.98	104.69	0	2.79	TRUE
Guangxi	1	0.99	264.31	0	2.64	TRUE
Chongqing	0.99	0.99	122.57	0	2.76	TRUE
Sichuan	0.98	0.95	32.29	0	1.58	TRUE
Guizhou	0.99	0.98	83.21	0	1.78	TRUE
Yunnan	1	0.99	179.92	0	1.92	TRUE
Shanxi	0.99	0.98	79.13	0	2.99	TRUE
Gansu	0.97	0.93	25.29	0	2.8	TRUE
Ningxia	0.98	0.96	41.35	0	2.92	TRUE
Qinghai	0.99	0.99	141.29	0	2.6	TRUE
Xinjiang	0.99	0.99	130.83	0	2.36	TRUE
Inner Mongolia	1	1	388.33	0	2.3	TRUE

45.5 Trend Forecast

In this paper, before forecasting the Midwest provinces housing prices trend, you need to set composed of five explanatory variables W = (GDP, POPUL, PCDI, INVEST, NCA) prediction model, and then predict the value of each index into the measuring income the regression model to predict housing prices. In predicting the explanatory indicators, due to the presence of non-linear argument may change with time curve, so using curve estimation can make the difference between actual data and theoretical data as small as possible. If the curve selection is good, it can better reflect the inner relationship between the variables and the independent variables, and the prediction of the dependent variable has a certain significance.

In this paper, we use a variety of general simulation forecasting methods, and compare the results of the calculation. According to the value of the coefficient, we can choose the optimal curve estimation model. Then you can obtain the predicted value of each index by calculating the interpretation model. Finally, the predictive value of each interpreted indexes into the regression equation, you can get Table 45.3 in the central and western provinces of the next three years of real estate forecast value.

Table 45.3 Average selling price (unit: RMB) forecast of residential buildings in midwest of China

	2014	2015	2016	2017	Trend
Shanxi	4,462.00	5052.78	4979.52	5336.23	Increase
Jilin	4,810.00	5544.81	6215.36	6945.62	Increase
Heilongjiang	4,517.00	4315.49	3466.16	1775.13	Decline
Anhui	5,017.00	5030.58	4813.23	4264.45	Decline
Jiangxi	4,971.00	5360.95	5354.03	5104.16	Stable
Henan	3,909.00	4573.12	5111.55	5697.72	Increase
Hubei	5,085.00	5280.68	5401.68	5396.2	Stable
Hunan	3,830.00	3976.33	3762.25	3345.22	Decline
Guangxi	4,442.00	4799.62	5143.02	5505.7	Increase
Chongqing	5,094.00	5108.99	4734.39	4051.17	Decline
Sichuan	5,092.00	5155.31	5000.83	4653.68	Stable
Guizhou	3,694.00	3570.15	2958.95	1921.47	Decline
Yunnan	4,451.00	5015.19	5521.67	6085.51	Increase
Shanxi	4,823.00	4560.04	3719.8	2387.98	Decline
Gansu	4,234.00	5118.62	6077.87	7301.83	Increase
Ningxia	3,747.00	3757.27	3356.41	2686.79	Decline
Qinghai	4,294.00	4869.12	5475.11	6194.21	Increase
Xinjiang	4,057.00	4627.25	5031.55	5446.43	Increase
Inner Mongolia	3,833.00	4477.49	4617.53	4646.09	Increase

From Table 45.3, it can be concluded that the forecast value of the model is consistent with the actual price level in 2015, but after two years, the price level fluctuations may have a large deviation with the real value. Therefore, the predicted value after only two years as a judge future price movements of a signal, specific value may be due to changes in various indicators have a greater change.

45.6 Discussion

At present, domestic and foreign literature mainly using time series models, neural network forecasting model, gray forecast model from a macro perspective to analyze the relationship of the rates and fundamentals. In this paper, based on the theory of supply and demand in the market economy, to select five main factors affecting prices, through the use of traditional regression model and trend analysis from a microscopic perspective of future price movements in central and western provinces, in order to guide individuals and businesses better investment to better serve the economic development of the city. However, this article mainly because of limited data, the prices forecast does not consider the cost of construction, local policy, the current bank interest rates, inflation and so on, so the forecast value is only as an auxiliary tool to judge the trend of prices.

Of course, there are many factors that affect the price. For example, scholars often discuss the money supply, tax policy, loan interest rates, land policy, and so on, in addition to the current Chinese real estate purchase real name system, personal property registration system, new urbanization of migrant workers' housing demand, these new changes in how to affect the trend of housing prices need to further explore the study. However, with the continuous supply of affordable housing, limited credit, restriction and a series of macro-control policies and the introduction of the national economic growth mode change, we believe that price increases will become increasingly smaller and eventually easing.

References

1. Anglin P (2006) Local dynamics and contagion in real estate markets. In: The international conference on real estates and macro economy, Beijing, pp 19–24
2. Choy LH, Mak SW, Ho WK (2007) Modeling Hong Kong real estate prices. J Hous Built Environ 22(4):359–368
3. Decaro SW (1997) Correlations and copulas for decision and risk analysis. Manag Sci 45(2):208–224
4. Deng X, Li S (2015) Consumer demand, investment demand and housing price fluctuations. Southwest Univ Natl (Humanit Soc Sci) 10:99–103 (in Chinese)
5. Johansen S (1988) Statistical analysis of cointegration vectors. J Econ Dyn Control 12(2):231–254
6. Li D, Ma Z (2006) Grey GM (1,1) model in house price forecasting algorithm research. Enterp Econ 9:96–98 (in Chinese)

7. Liu D, Wang W (2008) Key drivers and future trends of housing prices in China. Manag Rev 9:3–10 (in Chinese)
8. Ma Y, Liu C (2014) China's real estate market price fluctuation and the monetary policy based on the numerical simulation of the DSGE model analysis. Tianjin Univ Financ Econ 1:40–50 (in Chinese)
9. Malpezzi S (1999) A simple error correction model of house prices. J Hous Econ 8(1):27–62
10. Seko M (2006) Housing prices and economic cycles. In: The international conference on housing market and the macro economy, Beijin, pp 19–24 (in Chinese)
11. Yan Y, Wei X et al (2007) Method for housing price forecasting based on TEI@I methodology. Syst Eng-Theory Pract 27(7):1–9
12. Yao X, Huang W (2001) Land and housing relationship. Real Estate Market 9:33–35 (in Chinese)
13. Zhang D, Zhou L (2004) The impact of customer demand on real estate prices. Real Estate Market 4:58–60 (in Chinese)
14. Zhang P, Yang H (2000) Study on the benchmark land price prediction model based on neural network. China Land Sci 9:33–35 (in Chinese)

Chapter 46
A Credit Rating Model for Online P2P Lending Based on Analytic Hierarchy Process

Lin Xu and Yong Zhang

Abstract The risk caused by the rapid development of online P2P lending attracts more and more attention from the public. This paper mainly establishes a credit rating model for online P2P lending based on Analytic Hierarchy Process. Among lots of qualitative and quantitative indices focused by lenders, we screened out 39 indices and then established a model for calculating the weight of each index group based on Analytic Hierarchy Process. Finally we got a comprehensive score for each online lending project, and investors can evaluate the advantages and disadvantages of each P2P platform based on this model. At the same time, the model can help investors to make a rational choice considering the balance between risk and return according to their personal preferences.

Keywords Analytic hierarchy process · Online P2P lending · Credit rating model

46.1 Introduction

46.1.1 Online P2P's Lending in China

P2P (peer-to-peer) lending is a kind of individual debit and credit behavior besides the governmental financial organizations or systems. Since 2005, represented by Prosper in the United States and Zopa in the United Kingdom, the number and size of online social lending platforms have experienced a spectacular growth in the past few years [7, 15]. In August, 2007, the first real online P2P platform Paipaidai (www.ppdai.com) was established. Since 2011, there came up an influx in the P2P industry, with the amount of platforms and annual trading volume increasing by 4–5 times per year [3, 6].

L. Xu · Y. Zhang (✉)
School of Mathematical Sciences, Beijing Normal University, Beijing 100875, People's Republic of China
e-mail: zhangyong@bnu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_46

46.1.2 A Model for Online P2P Lending

In light of its quasi-explosive growth and future expectations, there is a developing body of work that examines the opportunities and risks involved, as well as conflicts in interest. To prevent and reduce the credit risk of P2P and protect the rights of lenders, a credit rating model is developed in which indices are all from online P2P platforms [17]. There are some drawbacks about that model which represents the comprehensive influence on behalf of online P2P platform, but it doesn't represent the platform's security and doesn't provide investment advice. Therefore, investors cannot directly make a investment choice according to credit scores of WDZJ.

This paper sets up a credit rating model based on hierarchy analysis method with the purpose to help lenders to make choices that can meet their needs, so as to enable them to fully assess the risk of investment projects and make the best decisions. Credit rating method of this paper gives scores of 39 indices based on the analytic hierarchy process (AHP), calculating the index weights and getting a comprehensive score.

46.1.3 Introduction of AHP

Based on mathematics, the analytic hierarchy process (AHP) is a structured technology for organizing and analyzing complex decisions. It was developed by Thomas L. Saaty in the 1970s [10], and it has been extensively studied and refined since then.

Rather than prescribing a correct decision, the AHP helps decision-makers find ones that best suit their goals and their understanding for the problem. It provides a comprehensive and rational framework for structuring a problem about the decision, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions.

Users of the AHP first decompose their problems about decisions into a hierarchy of sub-problems that are more easily comprehended, each of which can be analyzed independently. The elements of the hierarchy can relate to any aspect of the problem about decisions—tangible or intangible, carefully measured or roughly estimated, well or poorly understood—all applying to the decision at hand.

Once the hierarchy is built, the decision-makers systematically evaluate its various elements by comparing them to each other, representing their impacts on an element above them in the hierarchy. Through making the comparisons, the decision-makers can use concrete data about the elements, but they typically use their judgments about the elements' related meaning and importance. It is the essence of the AHP—not just the underlying information, that can be used to perform the evaluations [14].

The AHP converts these evaluations into numerical values that can be processed and compared in the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision-making technologies.

In the final step of the process, numerical priorities will be calculated for each of the decision alternatives. These numbers represent the alternatives' related abilities to achieve the decision goal, thus decision-makers can directly make decisions via this process.

46.1.4 Process of AHP

1. Judgment matrix

$$C_k = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} \end{array}.$$

Pairwise comparisons are made with the grades ranging from 1–9. These pairwise comparisons are carried out with considering all factors.
The meaning of a_{ij}: decision-makers compare A_i with A_j according to Table 46.1.
Properties of matrix elements:

Table 46.1 Ranking criteria

Intensity of importance	Definition	Explanation
1	Equally important	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgement slightly favour one over the other
5	Much more important	Experience and judgement strongly favour one over the other
7	Very much more important	Experience and judgement very strongly favour one over the other
9	Absolutely more importance	Experience and judgement mostly favour one over the other
2, 4, 6, 8	Intermediate values	When compromise is needed

$$(i)\ a_{ij} > 0, \quad (ii)\ a_{ji} = \frac{1}{a_{ij}}, \quad (iii)\ a_{ii} = 1.$$

2. Ranking of priorities
   In fact, if these elements' weigh vector $W = (w_1, w_2, \ldots, w_n)^T$, comparing the A_j and A_j, $a_{ij} = w_i/w_j$ is an accuracy, the judgement matrix is

$$\bar{A} = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & \cdots & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & \cdots & \cdots & w_n/w_n \end{pmatrix}. \tag{46.1}$$

   satisfying

$$\bar{A} \cdot W = \begin{pmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & \cdots & \cdots & w_2/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & \cdots & \cdots & w_n/w_n \end{pmatrix} \cdot \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} = n \cdot \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix},$$

$$\bar{A} \cdot W = n \cdot W,$$

   where W is the eigenvector of $\bar{A}$. From the decision-makers, $a_{ij} \sim w_i/w_j$ gets an approximate judgement matrix $A \sim \bar{A}$, so the eigenvalue of A is approximate to W. Consider $Ax = \lambda_{\max} x$ and normalize the column entries by dividing each entry by the sum of the column.
3. Checking for Consistency
   The next stage is to calculate a Consistency Ratio (CR) to measure how consistently the judgments are related to a number of samples of purely random judgments.

   - Calculate $\lambda_{\max}$ to lead to the Consistency Index.

$$CI = \frac{\lambda_{\max} - n}{n - 1}.$$

   - Calculate CR (Consistency Ratio) derived from Saaty's book by using the table below. The upper row is the order of the random matrix, and the lower row is the corresponding index of consistency for random judgments (Table 46.2).

Table 46.2 Consistency ratio

n	1	2	3	4	5	6	7	8	9	10
CR	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Each of the numbers in this table is the average of *CI*'s deriving from a sample of randomly-selected reciprocal matrices of AHP method.

- An inconsistency of 10 % or less implies that the adjustment is small as compared to the actual values of the eigenvector entries. A *CR* as high as, say, 90 % would mean that the pairwise judgments are just almost random and completely untrustworthy! In this case, comparisons should be repeated [1, 8, 15].

46.2 Variable Selection

46.2.1 Data Section

In this paper, the chosen platforms obey the rules of laws; except for that, other requirements are listed as following [17]:

(1) Annual interest rate ≤36 %, and the period of P2P's being online should be more than 6 months.
(2) In order to prevent platforms to build a capital pool, it is required that P2P platform monthly volume ≥100 million yuan and the time-weighted monthly volume ≥200/(thousand × month).
(3) Borrowers per month ≥10, investors per month ≥100.
(4) Considering online P2P platforms' financial indices, registered capital and risks, this model assumes average loan per borrower ≤ the maximum of registered capital, risk reserves and half of the registered capital from credit guarantee companies.

46.2.2 Variable Description

The names and meanings of all variables and parameters as well as the determination of principal parameters in the model are listed in this section [2] (Tables 46.3, 46.4 and 46.5).

$$x_4 = 100 \times \frac{\ln(Q_i) - \ln(10^6)}{\ln(Q) - \ln(10^6)}, \quad x_{22} = \frac{L}{(R \times c + V + G \times 0.5 \times c)},$$

$$x_5 = x_4 \times t, \qquad x_{23} = \frac{L}{Z}[\text{Appendix}],$$

$$x_{21} = \frac{x_{27}}{x_{28}}.$$

Explained variable is not only affected by quantity variable, but also affected by quality variable at the same time. Quantity variables are calculated through using log function, then standardizing like x_4, quality variables are shown in Appendix.

Table 46.3 Parameters in the model

Parameters	Parameters meaning
M	Comprehensive score
z_i	First-level indices: z_1—finance, z_2—management, z_3—operation, z_4—guarantee agency
y_i	Second-level indices $i = 1, \ldots, 13$
x_i	Third-level indices $i = 1, \ldots, 39$
a_i	The weight of each first-level index
b_i	The weight of each second-level index
c_i	The weight of each third-level index
t	The period of loan
Q_i	The volume of platform i
Q	The maximum volume of platform
C	Withdrawal amount
L	Loan amount
R	Registered capital
c	Financial leverage ratio
V	Venture capital
G	Registered capital of credit guarantee company
Z	Score of registered address

Table 46.4 Secondary indices definition

y_1	Return on investment	y_6	Transparency	y_{11}	Brand
y_2	Volume	y_7	Dispersion	y_{12}	Third-party management
y_3	Revenue	y_8	Liquidity	y_{13}	Third-party guarantee
y_4	Profit	y_9	Leverage		
y_5	Autonomy	y_{10}	Popularity		

Table 46.5 Dissonance-attribution hierarchy

Second-level indices	Third-level indices [4, 5, 9, 11–13, 16]
y_1 Return of investment	x_1 Risk-benefit ratio
y_2 Volume	x_2 Volume per month
y_4 Profit	x_5 Risk of return
y_6 Transparency	$x_6 \sim x_{18}$ (Appendix 1)
y_7 Dispersion	x_{19} Per capita investment
	x_{20} Per capita loan amount
	x_{21} Loan concentration
y_8 Leverage	x_{22} Uncollected leverage
	x_{23} Reginal leverage
y_9 Liquidity	x_{24} Duration
	x_{25} Credit assignment
	x_{26} Net worth (Appendix 1)
y_{10} Popularity	x_{27} The number of investors
	x_{28} The number of borrowers
y_{11} Brand	x_{29} Acceptance degree of funds
	$x_{30} \sim x_{39}$ (Appendix 1)

46.3 Modeling

The comprehensive score is computed out through the formula below:

$$\begin{cases} \mathrm{M} = \sum_{i=1}^{n_1} a_i z_i \\ z_i = \sum_{j=1}^{n_2} b_j y_{j(i)} \\ y_{j(i)} = \sum_{k=1}^{n_3} c_k x_{k(j)} \end{cases} \Longrightarrow M = \sum_{i=1}^{n_1} \sum_{j=1}^{n_2} \sum_{k=1}^{n_3} a_i b_j c_k x_{k(j)}, \tag{46.2}$$

where, using AHP determines all levels' weights of indices—a_i, b_i, c_i, establishing a tree hierarchy between second-level and third-level index membership. Start from the top layer and determine the weights of each layer.

Make a judgment matrix and a consistency test, then normalize the matrix, with calculating the weights (Fig. 46.1).

Compare the importance of each first-level index in goal M to generate the judgement matrix A:

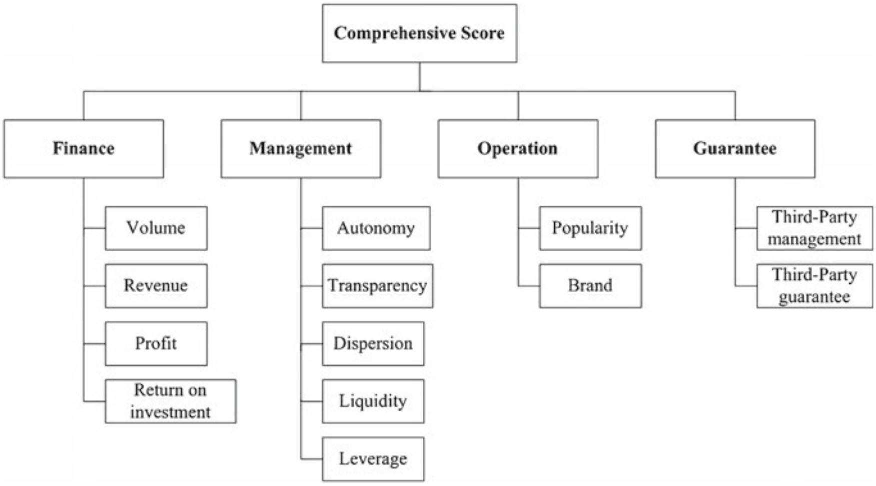


Fig. 46.1 Score tree

$$A = \begin{array}{c} \\ z_1 \\ z_2 \\ z_3 \\ z_4 \end{array} \begin{array}{c} \begin{array}{cccc} z_1 & z_2 & z_3 & z_4 \end{array} \\ \begin{pmatrix} 1 & \frac{1}{5} & \frac{1}{3} & 2 \\ 5 & 1 & 3 & 3 \\ 3 & \frac{1}{3} & 1 & 3 \\ \frac{1}{2} & \frac{1}{3} & \frac{1}{3} & 1 \end{pmatrix} \end{array}.$$

$$A = \begin{bmatrix} 1 & 0.2 & 0.33 & 2 \\ 5 & 1 & 3 & 3 \\ 3 & 0.33 & 1 & 3 \\ 0.5 & 0.33 & 0.33 & 1 \end{bmatrix} \xrightarrow[\text{Column Sums}]{\text{Normalized}} \begin{bmatrix} 0.11 & 0.11 & 0.07 & 0.22 \\ 0.53 & 0.54 & 0.64 & 0.33 \\ 0.32 & 0.18 & 0.21 & 0.33 \\ 0.05 & 0.18 & 0.07 & 0.11 \end{bmatrix} \xrightarrow{\text{Row averages}} X = \begin{bmatrix} 0.13 \\ 0.51 \\ 0.26 \\ 0.10 \end{bmatrix}.$$

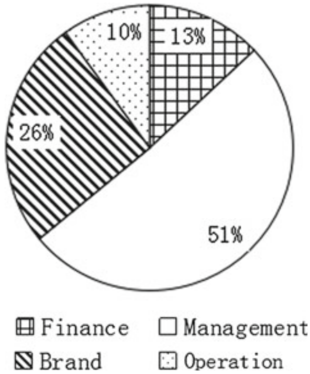
Column Sums $\quad 9.5 \;\; 1.86 \;\; 4.66 \;\; 9 \qquad\qquad 1.00 \;\; 1.00 \;\; 1.00 \;\; 1.00 \qquad\qquad$ Priority vector

$$\begin{bmatrix} 1 & 0.2 & 0.33 & 2 \\ 5 & 1 & 3 & 3 \\ 3 & 0.33 & 1 & 3 \\ 0.5 & 0.33 & 0.33 & 1 \end{bmatrix} \begin{bmatrix} 0.13 \\ 0.51 \\ 0.26 \\ 0.10 \end{bmatrix} = \begin{bmatrix} 0.54 \\ 2.24 \\ 1.12 \\ 0.42 \end{bmatrix} = \lambda_{\max} \begin{bmatrix} 0.13 \\ 0.51 \\ 0.26 \\ 0.10 \end{bmatrix}.$$

Determine the weight vectors z_1, z_2, z_3, z_4 of M based on A.
Calculate the weight vector and consistency test:
$\lambda_{\max} = \text{average}\{0.54/0.13, 2.24/0.51, 1.12/0.26, 0.42/0.10\} = 4.26$;
Weight vector (eigenvector) $\omega = (0.13\ 0.51\ 0.26\ 0.10)^T$;
Consistency index, *CI* is found by $CI = \frac{\lambda_{\max} - n}{n-1} = \frac{4.26-4}{4-1} = 0.087$;
Consistency ratio $CR = \frac{CI}{0.9} = \frac{0.087}{0.90} = 0.078 < 0.1$;
so the evaluations are consistent.

According to formula (46.1), the comprehensive score $M = 0.13z_1 + 0.51z_2 + 0.26z_3 + 0.1z_4$ (Fig. 46.2).

Fig. 46.2 Pie chart of each level indices



Using the same method, the weight vectors of second-level indices for each level can be calculated.

The matrix of each level indices, the weights and the analyses of consistency are as the following:

$$B_1 = \begin{array}{c} \\ y_1 \\ y_2 \\ y_3 \\ y_4 \end{array} \begin{array}{c} \begin{array}{cccc} y_1 & y_2 & y_3 & y_4 \end{array} \\ \begin{pmatrix} 1 & \frac{1}{3} & \frac{1}{3} & 1 \\ 3 & 1 & 1 & 3 \\ 3 & 1 & 1 & 3 \\ 1 & \frac{1}{3} & \frac{1}{3} & 1 \end{pmatrix} \end{array}, \quad B_2 = \begin{array}{c} \\ y_5 \\ y_6 \\ y_7 \\ y_8 \\ y_9 \end{array} \begin{array}{c} \begin{array}{ccccc} y_5 & y_6 & y_7 & y_8 & y_9 \end{array} \\ \begin{pmatrix} 1 & \frac{1}{3} & \frac{1}{5} & \frac{1}{2} & 1 \\ 3 & 1 & \frac{1}{3} & 3 & 3 \\ 5 & 3 & 1 & 6 & 6 \\ 2 & \frac{1}{3} & \frac{1}{6} & 1 & 1 \\ 1 & \frac{1}{3} & \frac{1}{6} & 1 & 1 \end{pmatrix} \end{array}.$$

In the following formulas, subscript 1 and subscript 2 stand for the results of matrix B_1 and B_2 respectively.

The maximum eigenvalues: $\lambda_1 = 4.0000$; $\lambda_2 = 5.0989$;

Weight vectors (eigenvector): $\omega_1 = (0.125, 0.375, 0.375, 0.125)^T$;

$\omega_2 = (0.0755, 0.2276, 0.5190, 0.0963, 0.0815)^T$;

Consistency Index: $CI_1 = \frac{4-4}{4-1} = 0$; $CI_2 = \frac{5.0989-5}{5-1} = 0.024725$;

Random Consistency Index: $RI_1 = 0.90$; $RI_2 = 1.12$.

Consistency ratio: $CR_1 = \frac{0}{0.90} = 0 < 0.1$; $CR_2 = \frac{0.024725}{1.12} = 0.022 < 0.1$.

They all have passed the consistency test.

Therefore, financial indices $z_1 = 0.125y_1 + 0.375y_2 + 0.374y_3 + 0.125y_4$;

management indices $z_2 = 0.0755y_5 + 0.2276y_6 + 0.5190y_7 + 0.0963y_8 + 0.0815y_9$.

Since the operation matrix and the guarantee matrix each has only two indices, the two weights can be more easily calculated. In this model, under the assumption of the operation index, both popularity and brand are 50 %; also under the assumption of the guarantee index, both third-party management and third-party guarantee are 50 %.

So, $z_3 = 0.5y_{10} + 0.5y_{11}$; $z_4 = 0.5y_{12} + 0.5y_{13}$.

Following the process above, we can calculate the weights of third-level indices.

Table 46.6 Comprehensive weights of credit rating model

First level index	Weight of the first level index	Second level index	Weight of the second level index	Comprehensive weight
z_1 Finance	0.13	y_1 Return on investment	0.125	0.01625
		y_2 Volume	0.375	0.04875
		y_3 Revenue	0.375	0.04875
		y_4 Profit	0.125	0.01625
z_2 Management	0.51	y_5 Autonomy	0.0755	0.0385
		y_6 Transparency	0.2276	0.116
		y_7 Dispersion	0.519	0.265
		y_8 Liquidity	0.0963	0.191
		y_9 Leverage	0.0815	0.0416
z_3 Operation	0.26	y_{10} Popularity	0.5	0.13
		y_{11} Brand	0.5	0.13
z_4 Guarantee	0.1	y_{12} Third-party management	0.5	0.05
		y_{13} Third-party guarantee	0.5	0.05

Therefore, the weights related to first-level and second-level indices of credit rating model (46.1) are calculated (Table 46.6).

The global priorities also have passed the consistency test, $CR < 0.1$. For the third-level indices, the weights can be calculated using the above AHP method, which is not stated here.

46.4 Case Study and Conclusion

Based on the above approaches, this paper evaluated the comprehensive scores of Renrendai (www.renrendai.com) and Weidaiwang (www.weidai.com.cn), namely:

$W(\text{Renrendai}) = \sum_{i=1}^{13}(ab)_i y_i = 85 \times 0.01625 + 71.58 \times 0.04875 + 65.26 \times 0.04875 + 50 \times 0.01625 + 75 \times 0.0385 + 53.87 \times 0.116 + 59.16 \times 0.265 + 70.12 \times 0.191 + 36.17 \times 0.0416 + 84.85 \times 0.13 + 54.78 \times 0.13 + 95 \times 0.05 + 90 \times 0.05 = 75.98$,

$W(\text{Weidaiwang}) = \sum_{i=1}^{13}(ab)_i y_i = 80 \times 0.01625 + 88.07 \times 0.04875 + 92.15 \times 0.04875 + 43.77 \times 0.01625 + 80 \times 0.0385 + 41.58 \times 0.116 + 20 \times 0.265 + 25 \times 0.191 + 85 \times 0.0416 + 74.6 \times 0.13 + 69.8 \times 0.13 + 90 \times 0.05 + 95 \times 0.05 = 60.33$.

According to the statements above, Renrendai gets a more comprehensive score than Weidaiwang, thus indicating that the former has a higher credit rating than the

Table 46.7 Scores of the two examples' second-level indices

	y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}	y_{11}	y_{12}	y_{13}
Renrendai	85	71.58	65.26	50.00	75	53.87	59.16	70.12	36.17	84.85	54.78	95	90
Weidaiwang	80	88.07	92.15	43.77	80	41.58	20	25	85	74.6	69.8	90	95

latter. Through the second-level indices, Weidaiwang has higher profit and revenue, but lower dispersion and liquidity, so its comprehensive score is not that high. Even though Renrendai is lower than Weidaiwang on profit and revenue, it has a better dispersion and liquidity. To sum up, if lenders have preferences to risk and pursue high profits, they may choose Weidaiwang, while for the others averting risks, Renrendai will be more suitable for them (Table 46.7).

On the basis of previous researches, this paper analyzed the credits of online P2P lending platforms. The innovation: this paper introduced AHP method to establish a credit-rating model. The key work:

1. The paper figured out the importance of 39 indices which are divided into four groups according to their properties.
2. The paper established a credit rating model for online P2P lending based on AHP.

By comparing the comprehensive scores and the index score for each level, it is expected that people can find out the online P2P platforms which best suit them.

Acknowledgments This project was supported by National Natural Science Foundation of China (11501035) and the Fundamental Research Funds for the Central Universities under Grant 2013YB54.

Appendix

1. According to the nature of the parameters, theses indices are all Qualitative variables which are divided into the two cases as below.This paper does no statistical analysis more about them (Tables 46.8 and 46.9).
   - Generally quality variable describes the existence of some feature, according to the presence or absence, a dummy variable is set to be 0 or 1. If it exists, there is a score of 1 (meaning in this model, the score is 100), or 0 (meaning in this model, the score is 0).
   - If there exists a narration, we can make assessments depending on its completion and authenticity, giving a score between 0–100.

2. $$\text{Regional leverage} = \frac{\text{Amount to be collected per month}}{\text{City integral}}.$$

Table 46.8 $x_6 \sim x_{18}$

x_6	Loan information	x_{11}	Loan credit rating	x_{16}	Operating data
x_7	Borrowing words	x_{12}	Company licenses	x_{17}	Investor meeting
x_8	Overdue rate	x_{13}	Corporate juridical person	x_{18}	Investigation report
x_9	Blacklist	x_{14}	Company team		
x_{10}	Loan account information	x_{15}	Office environment		

Table 46.9 $x_{30} \sim x_{39}$

x_{30}	Shareholders information	x_{34}	Operation time	x_{38}	Negative events
x_{31}	Team capability	x_{35}	Registered address	x_{39}	Ranking
x_{32}	Independent research	x_{36}	Venture capital		
x_{33}	Risk factors	x_{37}	Media report		

City integral can be calculated out through the following formula

$$y = \begin{cases} 100 & x \leqslant \mu, \\ 100 - \frac{8}{10}(x - \mu) & \mu < x < 10^5, \\ 20 - \ln(\frac{x}{10^5}) & x > 10^5, \end{cases} \tag{46.3}$$

where $\mu =$ per capita monthly salary $\times$ city integral $\times$ line of credit(make it 10), assuming that $\mu = 6000$.

References

1. Al-Harbi KMAS (2001) Application of the AHP in project management. Int J Proj Manag 19(1):19–27
2. Brans J, Mareschal B (2010) How to decide with promethee
3. CBN New Economic Research Center (2013) 2013 China P2P debit and credit service industry white book. China Economic Publishing House, Beijing
4. Chen D, Han C (2012) A comparative study of online P2P lending in the USA and China. J Internet Bank Commer 17(2):1
5. Dong J (2013) Offline risks and countermeasures of P2P lending platforms-taking Yixin P2P platform as an example. Secur Future China 2013(7):495–503 (in Chinese)

6. Fang W, Jiang Z et al (2014) On theories, practices and regulations on internet finance. China Economic Publishing House, Beijing (in Chinese)
7. Gonzalez L, McAleer K (2011) Determinants of success in online social lending: a peak at US prosper & UK ZOPA
8. Haas R, Meixner O (2009) An illustrated guide to the analytic hierarchy process, lecture notes, institute of marketing and innovation. University of Natural Resources. http://www.boku.ac.at/mi/
9. Koutrouli E, Tsalgatidou A (2012) Taxonomy of attacks and defense mechanisms in P2P reputation systems—lessons for reputation system designers. Comput Sci Rev 6(2):47–70
10. LaValle IH, Bard JF et al (1991) The analytic hierarchy process: applications and studies
11. Lee E, Lee B (2012) Herding behavior in online P2P lending: an empirical investigation. Electron Commer Res Appl 11(5):495–503
12. Li S, Lin Z et al (2015) How friendship networks work in online P2P lending markets. Nankai Bus Rev Int 6(1):42–67
13. Meyer T, Heng S et al (2007) Online P2P lending nibbles at banks' loan business. Deutsch Bank Res 2(1):39–65
14. Saaty TL (2008) Relative measurement and its generalization in decision making why pairwise comparisons are central in mathematics for the measurement of intangible factors the analytic hierarchy/network process. RACSAM-Revista de la Real Academia de Ciencias Exactas, Fisicas y Naturales Serie A Matematicas 102(2):251–318
15. Saaty TL, Vargas LG (2012) Models, methods, concepts and applications of the analytic hierarchy process, vol 175. Springer Science & Business Media, Heidelberg
16. Sun HM, Zou WN (2014) Research on the B2B trust evaluation model based on multi-agent under the e-commerce environment. Oper Res Manag Sci 5:031
17. Yingcanzixun (2016) Rating indices details of P2P platforms' development. http://bbs.wdzj.com/thread-139449-1-1.html. Accessed 03 Jan 2016

Chapter 47
An Empirical Study on the Prisoners' Dilemma of Management Decision Using Big Data

An Yang, Xin Lan, Lielin Huang and Yuling Wang

Abstract It is generally expectations about the precise management decisions in the era of Big Data. However, this paper found some difficulties in management decision using big data through empirical research. In this paper the key problem found by the management performance of factor analysis and regression analysis from three dimensions, and analyzed the formation mechanism and causes of the problem, combined with the prisoner's dilemma game model, derived measures to solve these problems. This paper presents the XYZ combination of strategy model for management decision. It has certain guiding significance for the application of big data to management decision.

Keywords Management decisions · Big data · Plight · Measures · Empirical study

47.1 Introduction

47.1.1 Important Significance of Big Data

With the advent of "big data era", it has been able from the "Internet +" that produce vast amounts of data to get accurate predictions for business decisions. By tracking and targeting customer groups, companies will be basing on the mass of data to infer consumer preferences and interests, converting to a precise target customers to boost sales to meet the precise needs of the individual. Big Data is a new stage of development of business intelligence. As the growing fastest technological innovation strength and solving the employment of backbone, management decision-makers must be conscious to accumulate data, And seek new ways that use big data to predict and analyze issues of commercial value.

A. Yang · L. Huang · Y. Wang
Jincheng College of Sichuan University, Chengdu 611731, People's Republic of China

X. Lan (✉)
China West Normal University, Nanchong 637002, People's Republic of China
e-mail: 43717828@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_47

Big Data in 1980 first proposed by Toffler [13], nature magazine launched a special issue of Big Data in 2008, McKinsey company pointed that the data will be the next innovation, competition and productivity frontier. Gartner Inc. [6] gave the definition of big data: Large capacity, fast generating rate, the value of such a diversity of information. Schönberger [12] proposed the characteristics and changes of the era of big data, big data beginning in global universal. From the attention to the overall transformation of the individual concerned. Premier Li Keqiang in "2014 Government Work Report Of China", also referred to "big data", And clearly pointed out that the big data will be leading the development of Chinese industry emerging industries in the future, Big Data era has arrived. Since then, research on big data also grew up massive camel. However, less from the angle of management decisions, research on large data applications practical problems and countermeasures.

47.1.2 The Dilemma of Management Decisions Using Big Data

Schönberger [12] proposed a big data era no longer rely on random sampling and causation, but the data of comprehensive, overall and relevance of observation. Enterprises in order not to be eliminated by the large competitors in the ever-changing data environment, it is necessary to analyze the data generated by operating activities, and the results of the analysis of information as a basis for management decisions one. Prediction, decision-making and positioning of technical content and accuracy greatly improved under the big data, effective use of big data become decision-makers to identify opportunities to avoid the risk of key. However, managing a large number of messy data is no small challenge. Meter through data analysis to describe the differences between consumers of virtual image and the real image, the results of data analysis are cold, the consumer behavior is contingent. Therefore, the analysis of the results with the real data may be poles apart. For management decision makers, they must make up for the huge gap between the emotional and the rational consumer psychology between the calculated data. This is a very professional thing, often only large companies can do it.

47.2 Empirical Research Hypothesis

47.2.1 Related Concepts

In order to verify the management decision-making application effect of big data. The dependent variable of this study is the enterprise performance. Bernadin [14] pointed that the performance reflects the people to engage in an activity achievements or outcomes. Related scholars proposed for the evaluation of business performance of different metrics: Woo and Willard will be grouped into five metrics: profitability, cash flow changes, relative market share, sales and market share changes. Profitability, level of innovation and growth potential three dimensions affect business performance [4]. Use of growth and profitability to measure corporate performance [15]. According to the above literatures for measuring enterprise performance. This study found that using the growth performance can better reflect the characteristics of the decision makers. So we chose business performance situation the last three years. With Three measures: annual sales growth rate, net profit growth rate and relative market share, measuring enterprise performance.

The argument of this study is big data perspective, enterprise performance related dimensions. Colombo and Grilli [1] held that entrepreneurial resources and business performance there was a significant correlation. Some domestic scholars had studied the relationship between market orientation and business performance, corporate entrepreneurship, knowledge capital, social resources of influencing mechanism influence enterprise performance.

We find that although the information resource is listed as an important dimension of influence firm performance. With the advent of the era of big data, data quickly, storage, massive dataset mining will be impacting on product innovation, marketing. Thus affect the corporate performance.

Combination of the above literature analysis, in this study, from the following dimensions of management decision-making application present situation of big data and the relationship between enterprise performance dependent variable.

47.2.2 Dimensional Data Analysis Capabilities and Enterprise Performance Management Decision-Makers

Makers of expertise, data analysis capabilities and experience connections will have a certain influence corporate performance. Foreign scholars had researched on the Management team conflict, cohesion, communication, cognition, the team leader affect company performance. As a business-risk sexual behavior, using big data to predict and accurate decisions on the basis of risk minimization steady success had become the direction of decision-makers need to work. Eric [2] from the "lean production" concept, proposed Lean Startup theory, Eric Ries thought Lean Startup was an innovative approach to the evolving Promote enterprise "verification study". At minimum cost and effective way to verify whether the product meets customer needs, and flexibility to adjust the direction. Li [9] pointed that in the process of decision-making, decision-makers need to base on knowledge and technology. According to our visited the business incubator park in 2015, found that decision-makers expertise and contacts circle of influence on business performance. For this Situation, based on new requirements for big data management capabilities, the following assumptions:

Hypothesis 1_a ($H1_a$): policymakers to accumulate experience and positive influence on enterprise performance

Hypothesis 1_b ($H1_b$): data analysis decision-makers and business performance positively correlated

Hypothesis 1_c ($H1_c$): policy-makers have learned expertise and enterprise performance positively correlated

47.2.3 Decision Data Dimensions and Enterprise Performance

Quantitative management originated in the United States, dating back to the early 19th century scientific management theories of the 20th century by Taylor, decision theory by Simon [11]. Another source of quantitative management theory of the 19th century 30–40 Comte's positivism proposed [3]. Until 2007, Hubbard was first proposed data decision, he believed that anything can be quantized including intangibles [5]. With the era of big data was presented. Martin [10] thought that the quantitative analysis itself was improved tools and methods, was big data era of business management. It can be used to track progress or predict future trends. Hubbard [10] believed that big data era, the fortune 500 are using the decision quantification method, amount of high information value is generally customers has never been quantified, one is to quantify the economic value of things and its attention often inversely proportional. Using quantitative data to understand how to calculate the risk is the key to understanding the value of information. Laursen [8] based on business analysis of big data added some new era of precision marketing approach and case. Lan [7] proposed the concept of precision entrepreneurship in a big data environment contingency relations function. We propose the following hypothesis to be tested:

Hypothesis 2_a ($H2_a$): target market precise positioning positively correlated with corporate performance

Hypothesis 2_b ($H2_b$): competitive position and business performance positively correlated

Hypothesis 2_c ($H2_c$): precise marketing strategy and business performance positively correlated

Hypothesis 2_d ($H2_d$): data of business decision-making and enterprise performance positively correlated

47.2.4 Big Data Environment and Enterprise Performance Dimensions

Decision makers of commercial data mining capacity is limited, The government and large enterprise master data can't be transparent and open public, policymakers will be confused. Lan [7] believed that open big data was an important business information treasure trove in big data environment. Therefore, we propose the following three hypothesis to be tested:

Hypothesis 3_a ($H3_a$): public data openness and positive correlation between corporate performance

Hypothesis 3_b ($H3_b$): commercial data mining degree of positive correlation between corporate performance

Hypothesis 3_c ($H3_c$): teaching data benefit with a positive correlation with corporate performance

47.3 Decisions Dilemma Is Proposed: Based on the Empirical Research

This study designed a questionnaire containing 7 magnitude scale (1 is totally disagree, 7 is totally agree). Using the Likert scale to measure the performance factors of enterprises, it was required the surveyed sample depending on the degree of identity to score. In the questionnaire of reaction test. Firstly, in the Chengdu Gaoxin district technological innovation service centre, chose 100 decision makers to issue forecasting questionnaires, asking for filling out the firm the performance of current situation and its impact factors. Then, using SPSS20.0 software to analyze the reliability and validity of the 100 forecasting questionnaires, removed the project variables both "management ability" and "innovation patent holder number", resulting that construct validity and KMO test values have been increased. It reached the questionnaire reliability and validity requirements. And the final enterprise performance influence factor scale (table omitted) contains 10 measurement questions.

This study through the channels of Business Incubation Association in 2015, conducted a sampling questionnaire of issuance in Beijing, Chongqing and Chengdu 3 areas' the high-tech industrial development zone or science and technology park of innovation and entrepreneurship service centre. At the same time, the students of Sichuan university Jincheng college and west normal university, organized a sampling survey of enterprises around the school. The selection of respondents were all the specific management decision makers.

From issuing and collecting the questionnaires had been continued for one year. The survey distributed a total of 500 questionnaires, 478 questionnaires were recovered actually, recovery rate was 96 %. Among of 448 were valid questionnaires, the effective rate was 94 %. These questionnaires were distributed equally at the region, and the selection of industry samples are representative. The sample were distributed in the information technology, electronic commerce, environmental protection and energy saving, catering food, education consulting, and creative cultural 6 industries.

47.3.1 The Process of Empirical Research

This study has carried on the descriptive statistics and reliability and validity test to the recycling sample data. If Crobancha coefficient greater than 0.7, the measure was credible. Reliability analysis showed that, policymaker dimension was 0.644, digitization decision dimension was 0.958, and the big data environment dimension was 0.943. Therefore, the sample passed the reliability test.

This study adopted the principal component factor analysis method, the maximum variance rotation method. Using SPSS20.0 software checked out the Bartlett sphericity observation was 1623.250, the corresponding probability close to zero, the significant "level a" equal to 0.05. "probability p" less than the significant "level a", thus, the null hypothesis of Bartlett sphericity test was refused. It followed that there are significant differences in unit matrix and correlation matrix. KMO test value greater than 0.7, explained that through the detect of factor analysis preconditions, conformed the factor analysis KMO metrics. As a result, factor analysis method can be used to observe under the respective of big data that the key factors of enterprise performance.

Factor analysis showed that, this study's each subject item belonged to many types of factor systematically, policymakers dimension analyzed to the 3 factors structure, factor loadings were among 0.722–0.746; digitization decision dimension analyzed to 4 factors structure, factor loadings were among 0.661–0.891; big data environment dimension analyzed to 3 factors structure, factor loadings were among 0.729–0.877, there was no significant cross burden among the factors. From each factor in the corresponding coefficient of load, loads were larger. It indicated that the study of measurement items was reasonable, the factors had a good convergence, and further illustrated that supposed the dimension structure established in line with the actual situation.

47.3.2 Hypothesis Verification Results

In the study, the hypotheses were verified by regression analysis model, the impact on enterprise performance about three-dimensional factors, including policymakers, digitization decision and big data environment, were formed model 1, model 2, model 3, as shown in Table 47.1, we found the management decision makers who applicated big data were caught in trouble.

Model 1 showed that the data analysis ability of the decision makers was very short, and digitization decision used rarely. Decision makers' experience and contacts $\beta = 3.058$, $P < 0.01$, relationship was very notable with the Corporate Performance, resulting hypothesis $H1_a$ got supported. However, to one's surprise, the relationship of the decision makers data analysis capability and Corporate Performance was week. And the relationship of decision maker's professional technology and Corporate performance was not obvious. So hypothesis $H1_b$, $H1_c$ had not been

Table 47.1 The verification results of firm's the performance of three-dimensional hypothetical model

Variables	Model 1	Model 2	Model 3
$H1_a$: Decision maker experience and contacts	3.058	–	–
$H1_b$: Decision maker data analysis capability	0.444	–	–
$H1_c$: Decision maker have learned professional technology	0.102	–	–
$H2_a$: Target market positioning accuracy	–	0.096	–
$H2_b$: Competitive advantage position	–	1.086	–
$H2_c$: Precision marketing strategy	–	0.026	–
$H2_d$: Digitization business decision	–	0.014	–
$H3_a$: Public data openness	–	–	1.187
$H3_b$: Commercial data mining degree	–	–	0.741
$H3_c$: Teaching data benefit	–	–	−0.02
F	119.599	63379.427	246.445
R^2	0.702	0.998	0.489

verified. This showed that the policymakers accepted education emphasis on imparting knowledge generally, less provided market and data practice opportunities.

Model 2 showed that the digitization decision had little effect on Business Performance. Target market positioning accuracy $\beta = 0.096,\ P < 0.01$, was related with Corporate Performance, resulting hypothesis $H2_a$ was verified. The competitive advantage position $\beta = 1.086,\ P < 0.01$, significantly affected on Corporate Performance, resulting hypothesis $H2_b$ got supported. Whether to adopt precision marketing strategy or to adopt digitization business decision, both influenced in Corporate Performance, but had little impact. So lead to hypothesis $H2_c$, $H2_d$ were verified. In general, management decision makers not only need to innovate, capital and experience, what's more important were selecting the target accurate market positioning and gaining the advantage of competition position.

Model 3 showed that decision makers to be investigated didn't obtain more benefit from the open Big Data. It showed that public data openness $\beta = 1.187$, $P < 0.01$, decision makers generally thought that government and professional organizations released the forecast data was more important, resulting hypothesis $H3_a$ was verified. Commercial data mining degree $\beta = 0.741$, $P < 0.01$, was related with Corporate Performance, lead to hypothesis $H3_b$ was verified. However, the teaching data benefit $\beta = -0.020$, was not interrelated with Corporate Performance, resulting hypothesis $H3_b$ not been verified. This suggested that government and educational institutions to do data services on the market was not effective. Just set up a business Incubation Park, build buildings, purchase of equipments and start classes were not enough, open and transparent data as well as data provided by market forecasts were more significant.

47.4 The Formation Mechanism of Decision Dilemma—Based on Prisoner's Dilemma Model

Now that, digitization decision had very important significance. Why the results of the above empirical analysis, the decision dimension suffered short shrift by decision makers seriously. The following to explore the formation mechanism of the problem through the prisoner's dilemma game analysis.

47.4.1 Establishment of Prisoner's Dilemma Model

Prisoner's Dilemma was proposed by Merrill Flood and Melvin Dresher in 1950. Then the theory was described by Tucker Albert in a prisoner, and named as "prisoner's dilemma", reflected the rational conflict relationship between the individual and the overall. It was to pursue the rational people whose maximize on their own interests, made themselves in trouble by self-dug. The performance of that when egoistic behaviors became the sole goal to pursue, it will lead to all individuals at a risk and overall profit was lost. So the final outcome was named Nash. It called the Nash equilibrium (also called non-cooperative equilibrium).

Supposing the society global gave the amount of 10 units feedback to management decision makers, there were A and B two decision makers to compete. As shown in Table 47.2, A and B were the same level. At the same time, market requirements for both policy makers were looking for the rational people whose maximize their own interests suitably. Furthermore, two decision makers were in a competitive, same information and repeated game contact.

47.4.2 Multiple Rounds of the Game and Its Results Analysis

In the first round of the game, two competitive decision makers both found digitization decision was rational and scientific, both of the management behaviors were

Table 47.2 The prisoner's dilemma matrix of digitization management decision

		Decision-maker A	
		Rely on data specification decision	Rely on personal connections decision
Decision-maker B	Rely on data specification decision	5, 5	1, 9-2
	Rely on personal connections decision	9-2, 1	5-2, 5-2

normative, so each got five units amount of market feedback (feedback proportional allocation of 5:5). It means that, A and B can distribute market feedback equally. However, in the environment of the lack of useful guidance, every decision maker only was to seek profit maximization, lead to the equilibrium was unsustainable. Resulting was easier to out of control. There are some policymakers started to explore that if there is any shortcut to reduce the cost and risk to get the largest interests.

In the second round of the game. One of the decision makers used the private relationship, did not use on the basis of digital specification decisions. Instead of seeking dominance to break the rules, finally with connections stakeholders shared market returns. Giving two units transfer to those connections. So got nine units maximum market feedback (feedback proportional allocation of 9:1). Even when the project was put into the market, only 7 units were obtained. However, comparing with the first round of the game, the interest had been greatly increased. Another decision maker still took data standard way of decision-making, only got 1 unit quantity, the minimum market feedback. So the decision maker was very dissatisfied on the outcome. After summarizing own way, also began to pursue personal connections to gain a dominant position in the market.

In the third round of the game, A and B both adopted the way that depended on connections to do decision. As a result, both gave two units surrender part of the profits to relevant connections, each got five units amount of market feedback (feedback proportional allocation of 5:5). However, release two units surrender part of the profits to relevant connections, each only get 3 units quantity market feedback. In the global, this yield was the lowest. This was the face of Nash equilibrium. Each participant only have seek the maximum value of its own benefits. However, the global situation did not achieve the maximum profit. Like the established models, both decision makers were in prisoner's dilemma.

Pay attention specially, the 10 units were social global market feedback to policy makers. There are four units quantity into non-enterprise actually (even the administrative institutions of public officials, or monopoly position oligopoly of large enterprises). But the enterprise should be encouraged only got 3 units quantity market back. If do not control this phenomenon in real time, In the long time, besides the stale corrupt social conduct is growing, it will cause the social overall interests of the heavy losses and tragic situation.

47.5 In the Analysis of the Causes of "Prisoner's Dilemma"

(1) "Information Asymmetry" Has not Been Fundamentally Improved by Using Big Data

In social activities, because the information cannot be shared, lead to the trading relationship between members and the contract arrangement are unfair, or the problem of market efficiency reduced, referred to as "information asymmetry". The innovation and entrepreneurship information disclosure and transparency is not enough. And common policy makers do not master a lot of technical information, policy information and business data, it is easy to cause the power rent-seeking, monopolistic competition, trade barriers and other issues.

Big data remain exist data monopoly and barriers, resulting that the enterprise is hard to come back again the data owner. Under the present, each enterprise is seeking self-interest maximization. In the absence of effective guidance, some of the data owner must use their mastery of the huge amounts of data, always grasp the market opportunities, and let these data.

(2) Repeated Game Has not Got Effective Intervention by External Forces

According to the principle of game theory, to break the Nash equilibrium of repeated game depend on effect of external force. This external force is mainly derived from the government behavior, legal and institutional reform.

In the current related field, the global government and social intervention is often weak. In the aspect of legal environment, to protect the technological innovation is not more enough. There are media to think, repeated game showed the public should have the courage to break the market monopoly power time to time.

At the same time, because of the achievements and examination, entrepreneurship policy standards and vulnerable get infected easily. Directly to aid money is able to make a quantitative comparison of the political achievement, while the entrepreneurship financial assistance is usually light weight, heavy quantity.

(3) Policymakers Lack the Power out of Repeated Games

Innovation and development report of China [16] shows that: the lack of innovation support, innovation main body is running out of steam, the phenomenon of lack of creative talents, these are hindering our country enterprise independent innovation development.

47.6 Strategies for Getting Rid of the "Prisoner's Dilemma"

According to the empirical analysis, game analysis and cause analysis, this study has formed on application of big data model management decisions three countermeasures, as shown in Table 47.3.

X strategy: private data control, decision-makers to build their own big database, based on a big database to create their own decision-making (Model II verification conclusion, variable $\mathrm{H2}_{a-d}$). Data resources must be reasonable and lawful management and control. Enterprises can't be too dependent on improving government and public platforms, in big data era of rapid development, companies need to create their own big database. To mitigate the risk of a lot of blindness asymmetric information, companies can work with some of the data owner, and thus share professional data, rather than rivalry; through their own social media platform, accelerate the establishment of its own database. Moreover, Google, Baidu and other Internet search platform and the Internet map of big data more powerful, easier to set up their own enterprise database through these channels.

Y strategy: open government and other public big data, policy makers can take advantage of an open big data to make decisions (Model III verification conclusion,

Table 47.3 Combination to get rid of the prisoner's dilemma strategies

Empirical findings and the corresponding variable	Get rid of the prisoner's dilemma combination countermeasures
X strategy: Model two verification conclusion, variable $\mathrm{H2}_{a-d}$	Private data control, decision-makers to build their own big database, according to CEM, ERP, APP and other big databases to create their own decisions
Y strategy: Model three verification conclusion, variable $\mathrm{H3}_{a-c}$	Big data open public big data, so that decision-makers from the open Baidu cloud Listed Company Government Information libraries mining valuable information to make decisions
Z strategy: Model one verification conclusions variable $\mathrm{H1}_{a-c}$	The balance of decision-makers, to get rid of the prisoner's dilemma is the key decision-makers how to grasp the balance point control (X strategy)and public (Y strategy) between the search, cognition and discerning

variable $\mathrm{H3}_{a-c}$). Data disclosure is an obligation of governments, public institutions and enterprises monopoly, open data is a major source of innovation and entrepreneurship information. Big data is originally an open resource on the Internet, we should return to the open nature. The Government should take the lead and opening up, the implementation of the strategy for public information disclosure and open data integration to support the country's existing enterprise information exchanges and cooperation, to maximize information sharing, comprehensive support independent innovation, breaking the original production technology and innovative ideas, data transparency by truly independent innovation of enterprises.

Z strategy: policy makers face the private and public balance (model a verification conclusion, variable $H1_{a-c}$). Key decision-makers to get rid of the prisoner's dilemma is how to grasp the balance point control (X strategy) and public (Y policy) between. Collected from the outside is incomplete, inaccurate data, will affect the accuracy of the data analysis, so policy-makers need to fully grasp the three key capabilities: search, cognitive and discerning. Policy makers need to continuously improve the quality of data analysis, optimize the data source, enhance the interpretation of the data processing capability, while actively respond to the wave of big data set data decision-making confidence, combined with corporate strategic planning big data embodiment, so that the data of the rational and according to.

In short, according to game theory, the establishment of a dynamic relationship between the government and all the game management decision makers can help get rid of the prisoner's dilemma. To create this game relationship, the government needs to regulate through legislative, administrative and economic means competition participants income structure change sides of the game, so that the individual interests are subordinate to the best overall interests. The government is no longer the dominant distribution of social resources for their own individual interests, the role of government after the change should be to provide basic security rules and allow fair competition policy and decision-makers in the $X - Y$ strategies to hold their balance.

Acknowledgments The quality and teaching reform project of higher education in Sichuan Province empirical research on plight and strategies of innovation and entrepreneurship; The key project of the Ministry of Education Information Management Center on MOOC The empirical research on innovation entrepreneurship education support system based on Big data environment (2014–2016).

References

1. Colombo MG, Grilli L (2005) Founders' human capital and the growth of new technology-based firms: a competence-based view. Res Policy 34(4):795–816
2. Eric R (2012) Lean startup. CITIC Publishing House, Beijing
3. He J, Wang J (1996) History of western sociology. Sichuan People's Publishing House, Chengdu (in Chinese)
4. Hu W, Zhang Y, Yang J (2010) Entrepreneurial orientation and performance transformation based on the ability to explore new business perspective, vol 2. Foreign Economics and Management (in Chinese)
5. Hubbard DW (2013) How to measure anything: finding the value of intangibles in business, vol 9. World Book Publishing Company
6. Ji C, Li Y et al (2012) Big data processing in cloud computing environments. In: 12th international symposium on pervasive systems, algorithms and networks (ISPAN), 2012. IEEE, New York, pp 17–23
7. Lan X, Yang A, Wu S (2015) The study on concepts and relations function accurately under large data entrepreneurial environment. Technol Mon 6:319–321 (in Chinese)
8. Laursen W (2013) Precision marketing methods and case: business analytics of big data era. People Post Press
9. Li B (2015) Research on the impact of big data business management decisions. Financ Times 11:118–123 (in Chinese)
10. Martin K (2013) Quantify: the era of big data business management. People's Post Published
11. Rothwell R (1994) Towards the fifth-generation innovation process. Int Mark Rev 11(1):7–31
12. Schonberg VM, Cook K (2012) Big data era-live, work and thinking big change. Zhejiang People's Publishing House, Hangzhou
13. Toffler A, Longul W, Forbes H (1999) The third wave. Strategy & Leadership
14. Woo CY, Willard G (1983) Performance representation in business policy research: discussion and recommendation. In: 23rd annual national meetings of the academy of management, Dallas
15. Zhang J, Cai L, Zhu X (2008) Social networks, resource acquisition performance and new ventures. Ind Technol Econ 5:87–90 (in Chinese)
16. Zhang W (2014) National innovation blue book: China's innovation and development report, vol 8. Social Sciences Academic Press, Beijing (in Chinese)
17. Zhao W, Liang Q (2010) Research on the relationship between technology acquisition mode and enterprise performance. Sci Res 5:741–746 (in Chinese)

Chapter 48
An Approach to the Creation of the Adaptive Control System for Integration of Nonsteady Power Sources into a Common Electric Power Grid

Romen Zakhidov and Abdulla Arifjanov

Abstract Growth of the population of the earth, increase of a standard of life of people—these factors inevitably conduct to growth of consumption of power resources. On the other hand, arising environmental problems, a prompt exhaustion of available sources of raw materials—all it demands more rational use of the received energy and acceptance of urgent measures on preservations of primary natural power resources for the future generations.

Keywords Electric power system · Power grid · Distributed power generation · Distributed generators · Smart Grid technology · Microgrid · Common power grid · Renewable energy sources · Effective control of the operation of power systems · Automatic control systems · Active-adaptive system of automatic operation control

48.1 Introduction

Modern processes of globalization, demography, development of innovative technologies and transition to a step of postindustrial development are connected with increase in consumer inquiries of a society. The analysis prospective estimations shows [1], that by 2030 consumption of primary power resources (PPR) in the world will essentially increase.

The fastest growth of consumption of power resources for prospective period is expected in developing countries. In these countries growth of consumption of power resources is expected at level about 70 %, at that time in the countries of the Organization of economic cooperation and development (ECD) no more than 15 %. It is caused by rapid growth of industrial production, number of population, an urbanization and transfer of economy of these countries into use of commercial

R. Zakhidov (✉) · A. Arifjanov
Institute of Power Engineering and Automation, Uzbekistan Academy of Science, Tashkent, Uzbekistan
e-mail: rzakhidov@mail.ru

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_48

kinds of the PPR. In the countries ECD rates of a gain of consumption the PPR for prospective period will make no more than 0.6 % a year, (almost in 3, 8 times below indicators of developing countries), that is connected with high level of a power infrastructure already created in these countries. At the same time the forecast shows, that at proceeding growth world demand for the PPR, the structure of supply and demand on them will vary aside more harmless kinds of fuel.

Energy satisfies basic needs and gives corresponding services; it is the important component of social development and economic growth. The problem consists in maintenance of demanded power services for increasing population of the world without consequences for environment which finally can become irreversible. The decision of this problem demands essential changes in world power balance. It is necessary to initiate changes now if the mankind wishes to reach successful continuous development.

48.2 Distributed Generation of Electricity—The Way to Solve the Problem

The future power supply system should combine large power stations without which are problematic electro supply of large consumers and maintenance of growth of power consumption. Large power stations allow raising voltage with generating to voltage of the main network on which there is a transport of the electric power to the large centers of consumption. Installations of the distributed generation, including on RES, work through distributive networks. The following level of a power supply system of the future will make mini-and micro-installations (mini-and micro-hydroelectric power station, wind generators, solar energy installations, fuel elements, etc.) which are connected on a low voltage and are established at small consumers, for example, in separate houses or on small enterprises, including agricultural.

In many industrially developed countries where reserves of own organic fuel are almost settled or were not available initially and which power is based, at the moment, on import deliveries, questions of use of nonconventional renewable energy sources (NRES) become more and more actual.

For developing countries, and the countries going today through economic crisis, the deficiency of the big capital investments excluding possibility of a construction of large traditional power stations is characteristic. At the same time installations with NRES, as a rule, have modular character and allow to put into operation rather low powers, increasing them as required.

Reduction of stocks of traditional sources of energy carriers and the tendency to increase of power efficiency force people to search more and more refined methods of use of traditional and nonconventional energy sources. According to the forecast, renewable energy sources will provide a quarter of a gain of world demand for energy carriers till 2035 and third of gain in electro generation sector. Potential resources of renewable energy sources make an essential share of requirements of mankind in power.

Recently systems of hybrid power supply become rather popular. They provide use of various energy sources. In these systems electric energy is generated with use of solar photo-electric panels, wind turbines or other energy installations. Generating of thermal energy for systems of heating, hot water supply and technological processes is carried out with use of solar collectors (flat and vacuum tubular), geothermal systems, and also other converters of thermal energy. The combination of various renewable energy sources is not only presence of such elements, as solar collectors, photo-electric panels, wind turbines, thermal pumps, but also use of a uniform control system for maintenance of effective work of these elements that makes a basis of stable hybrid system of power supply.

For an effective utilization of hybrid system of power supply with application of renewable energy sources (RES) it is necessary to co-ordinate intensity of receipt of energy with its expense consumers. Such coordination can be carried out on the basis of monitoring of the current information on receipt and power consumption and the management which is carried out by uniform system, constructed on the basis of modern information-communication technologies.

48.3 Smart Grid Technology and Solution of the Problem of Matching the Connection of Renewable Energy in the Common Electricity Grid

The analysis of possible ways of development of electric power industry shows presence of serious restrictions in development of branch within the limits of traditionally operating system. A possible exit from the developed situation is the concept of construction of intellectual networks of the power supply named Smart Grid (SG) [4] (the term is entered by Michael T. Burr in 2003 [2]). The given concept is considered as a basis of modernization and innovative development of electric power industry with application of last achievements of information-communication technologies.

The technological precondition of development Smart Grid, certainly, possibilities of local and global communication networks, including the Internet were break achievements of information, computer technologies.

On level of development Smart Grid is at a stage of transition from working out of the basic concept to the creation of national and international standards, realization of separate pilot and also of some industrial projects.

Traditionally operating electro power system without Smart Grid can be characterised as passive and centralized, especially regarding last chain—from distributive networks to consumers. In this part of a chain of delivery of the electric power—technology of Smart Grid most essentially changes functioning principles, offering new principles of the active and decentralized interaction.

The basic differences of traditionally operating electro power system in relation to principles of functioning Smart Grid can be considered on an example of a separate building as the end user. Now the building from the point of view of interaction with a distributive network (110/10/0, 4 KB) is practically completely a passive element. It first of all concerns building influences as consumer in real time (i.e. on the scale of current month, day, hour, second etc.) on the electric power generated and distributed by a network. The building cannot affect in any way neither volume of electric capacity, nor on the allocated resources of an infrastructure of a network (for example, on elements of distributive, transformer substations). Moreover, distributive networks in most cases do not possess the full information on a building power consumption in real time. Realization of current automatic systems of the account of energy in this context is till now most likely an exception and is used mainly with a view of the commercial account of the electric power usually within the limits of a monthly interval.

The commercial component of interaction, in turn, entirely depending on the above-stated technological part, also looks passive and unidirectional. Networks in frameworks of energy sale organizations learn about buildings and their requirements only during the moments of monthly commercial mutual calculations, thus treaty obligations, are updated not more often than an once in a year. Buildings (is more true, consumers in buildings) pay under the fixed, centralized tariffs extending on the whole areas, cities. Tariffs for end users change on-line organizational procedures with state participation on long intervals of time. Any feedback from the point of view of the information on a condition energy consumption in a building, interaction possibilities, especially in a mode of real time, at a building with networks and the more so the centralized manufacturers of energy are not present. Therefore manufacturers of the electric power generate and deliver the electric power in volume, in modes and at the cost, practically not dependent on a real condition of the electro consumer on the scale of real time. Thus, between a supply and demand there is no operative communication. From the point of view of reliability of functioning of such network in the conditions of deficiency of capacity and high requirements from the consumer such scheme is the extremely vulnerable as cannot operatively reveal a problem and react to them at level of consumers.

It is necessary to notice, that the current scheme from the point of view of power supply is completely unidirectional, i.e. the consumer only receives electric energy. And the described is passive-centralized scheme quite suited all till the certain moment in the conditions of the cheap electric power, inexhaustible possibilities as energy generators, and distributive networks. However times have changed. Growth of megacities, increase in cost of the electric power, requirements to quality of the electric power, expenses for development of a generating and distributive infrastructure, increase in risk of external threats (terrorism, cataclysms) evidently lead to change of strategy of development of a power market.

Technology Smart Grid is characterized by the several innovative properties meeting new requirements of the market among which it is possible to allocate the following:

(1) The active two-forked scheme of interaction in real time an information exchange of all between elements and participants of a network, from generators of energy to final devices in the form of electro consumers.
(2) Coverage of all technological chain of an electro power system, from energy manufacturers (as central atomic power stations, thermal power stations, hydroelectric power stations and independent diesel generating installations, solar individual generators, energy stores), electro distributive networks and end users.
(3) For maintenance of information data exchange in Smart Grid use of digital communication networks and data exchange interfaces is provided. One of the major purposes Smart Grid is maintenance of practically continuous operated balance between a supply and demand of electric energy. For this purpose network elements should exchange constantly among themselves the information on parameters of electric energy, consumption and generation modes, quantity of consumed energy and planned consumption, the commercial information.
(4) Smart Grid is able to be protected effectively and self-recovered from large failures, natural cataclysms, external threats.
(5) Smart Grid promotes optimum operation of an infrastructure of an electro power system.

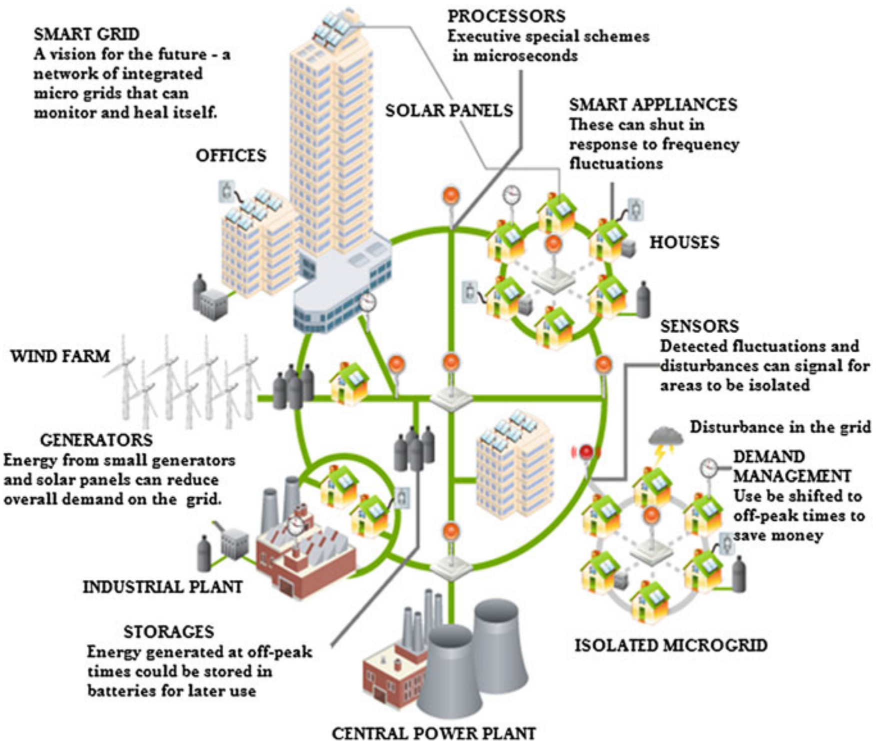


Fig. 48.1 General scheme of Smart Grid concept

(6) Thanks to modern technologies Smart Grid can be applied as in scales of buildings, the enterprises, and to usual house electric devices, for example, a refrigerator or a washing machine. Accordingly, all devices which are a part of Smart Grid, should be equipped by the means which are carrying out information interaction.

Technology Smart Grid assumes system transformation of electric power industry (power supply system) and touch all its basic elements: generation, transfer and distribution (including and municipal sphere), sale and scheduling (Fig. 48.1). It is supposed, that power supply system functioning will be carried out by close interaction between the centralized and distributed (decentralised) generating capacities. Photo-voltaic and wind energy distributed generating capacities as well many types of power installations on the basis of renewable energy sources (RES), first of all. Small generating electro installations are established directly at consumers and connected to a distributive electric network. These installations are called as “the distributed generators” and are considered as the “virtual” power stations functioning as a part of common electric network (CEN).

Management of the distributed generators is carried out as management of a micro network (micro grid) of the “virtual” power stations integrated into a global network and, thereby, in the electric power and capacity market that will promote increase of a role of the consumer in management of a power supply system.

48.4 Problem of Management of Integration of Non-stationary Energy Sources in a Common Electric Power Grid

On a way of creation of “virtual” power stations it is necessary to solve a number of the organizational-technological problems, one of which is the problem of connection of the distributed generators to a uniform network and management of their work. The distributed generators of an electricity integrated into CEN, represent difficult system in which communication between observable parametres and a system condition has difficult and ambiguous character. Therefore, the approach to management in the automatic control systems, based on management on output parametres, is inadequate as a matter of fact. In this case formation of operating influence should be carried out on the basis of data about a current condition of object of management.

Owners of microgenerators wish to have possibilities for purchases of reserve energy, and for implementation of sale of the surplus. Distinctions in types of used generators, technologies, loading modes on object of the owner of the microgenerator (in the house, office, at the enterprise), all these factors complicate introduction of uniform standards. Connection conditions to a uniform network of many generators depend on a condition of segments of a network, the general capacity of loading, the relation of capacity of loading to capacity of connected generators. At high total capacity synchronisation of set of the distributed generators creates a calculation and scheduling challenge.

The important problem becomes, for example, switching-off of a site of a network at failures.

Management of the distributed generators demands creation of a telecommunication network and the scheduling centre. In the centre (and can be, and in places of generation) should be carried out monitoring of network and loading conditions, market prices, processing of the information of the next manufacturers and salers, and on the basis of these data to be made decisions on use of capacities. In places of generators location there should be the special "clever" equipment capable on signals from the remote dispatching centre to operate by modes of the generator and energy consume of the object.

For connection of the generating equipment to a network the special equipment which is meeting the requirements whenever possible of remote control is required to the potential supplier of an electricity. The special counters transferring results of measurements in a mode of real time, also should become a standard element of architecture of the distributed generation. Expecting accruing complexities, the network companies frequently offer rather difficult and expensive procedure of certification of each concrete connection.

48.5 An Approach to the Creation of the Adaptive Control System for Integration of Non-steady Power Sources into a Common Electric Power Grid

The management of such power supply systems for which considerable territorial distribution and heterogeneity is characteristic, has the big urgency now. Heterogeneity of system can be connected with use of alternative sources of the electric power,as wind and solar power stations. Optimization of the network work should be made by several local intellectual devices.

The most perspective for use as system of electrosupply of remote consumers of small and average capacity represent now independent combined phonoelectric installations (PEI). The idea of the independent energy unit simplistically consists in

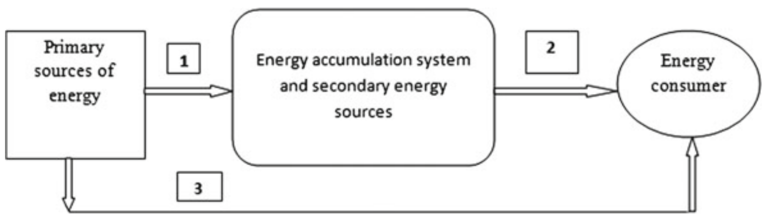


Fig. 48.2 Main components of autonomous power supply systems

the following (see Fig. 48.2). For the purpose of maintenance of a high power system effectiveness of independent power supply the energy developed by a primary energy source, should go directly to the consumer (a way I). During the periods of generation of superfluous energy it should be reserved by accumulation system (a way II). At deficiency of the energy developed by a primary source, accumulated energy should go to the consumer, covering available deficiency (a way III).

Application PEI in the areas removed from power highways, and also in mobile groups of different function is especially actual. However these energy sources, also, possess the lacks, basic of which are low power, inconstancy in time within days and year, unpredictability. At the same time by data meteostatisticans of merits and demerits of such renewable energy sources as solar radiation and a wind stream successfully compensate each other:

- at long sequence of cloudy days absence of the sun is compensated usually by wind presence;
- absence of solar radiation at night days also is compensated usually by wind presence;
- the wind on the statistican usually happens more strongly in winter months, whereas solar radiation—in summer.

The simplified structure of autonomous energy installation on RES is represented on Fig. 48.3. The structure of considered installation includes primary energy sources: photo-electric converters and wind unit. In this situation a key component of independent system is the system of accumulation. For maintenance of the most effective transformation of primary kinds of energy and satisfaction of needs of the consumer energy installation should be supplied by "clever" system of automatic control.

In power supply systems with renewable energy sources generally it is possible to use three management methods based on dump of surpluses of energy, accumulation of energy and loading change (Fig. 48.4).

These methods can be realized in the various ways regarding to all power supply system or its parts.

(1) System with dump of energy surpluses. Streams of energy of renewable sources exist constantly and if them not to use, they will be irrevocably lost. Nevertheless,

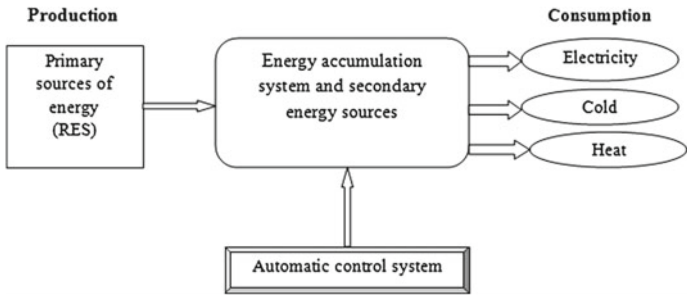


Fig. 48.3 Main components of an autonomous power plant on renewable energy sources (RES)

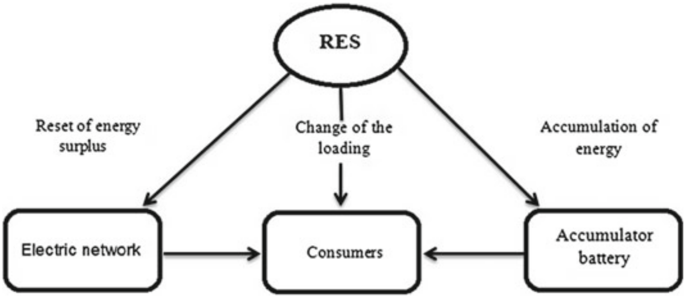
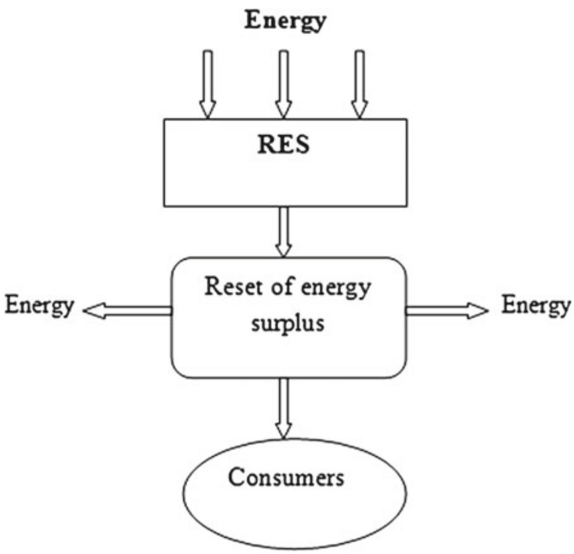


Fig. 48.4 Scheme of energy flow control methods from renewable energy sources (RES) to consumers

Fig. 48.5 The control system by reset of energy surplus



the management method based on dump of a part of this energy, can appear the most simple and cheap. Such management method is used, for example, on hydroelectric power stations, in heating systems of buildings with operated dampers and etc. (Fig. 48.7).

(2) Systems with stores (accumulators) of energy. Stores can accumulate energy of renewable sources as in its initial kind (for example, accumulators with hot water), and in transformed condition (storage batteries) (Fig. 48.5).

(3) Systems with loading regulation. Such systems support conformity between a supply and demand of energy at the expense of inclusion and switching off of necessary number of consumers. Such regulation can be applied in any systems, but it is the most favorable in the presence of the big number of diverse consumers (Fig. 48.6).

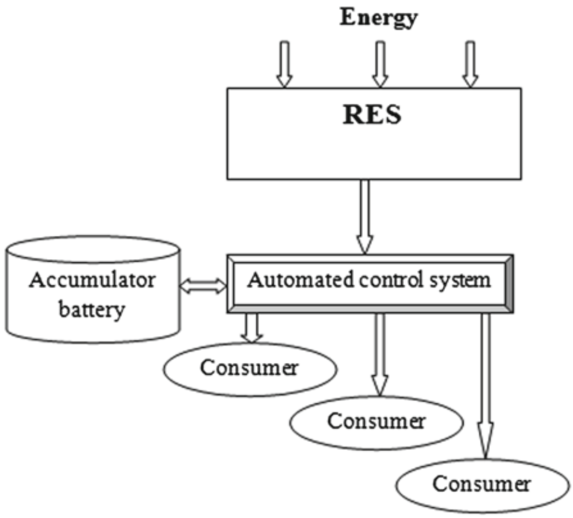


Fig. 48.6 Load control system

Modern systems of autonomous power supply, in the structure, as a rule, contain specialized microcontrollers which are intended for the solution specific tasks, connected with controllable process (for example-wind generator).

As an example we will consider the autonomous combined photo-wind electro power installation (PWEPI), also representing a typical example of complex technical system [3]. PWEPI includes the following subsystems, represented on Fig. 48.7.

Various processes by the physical nature are inherent in a considered power supply system:

- mechanical (transformation of wind stream energy to a mechanical energy of rotation);
- energetic (generation, conversion and transmission of electricity);
- informational (gathering, processing and an information transfer).

Such set of processes allows to use two-level of automatic control system (ACS), that usually takes place in real PWEPI [3]:

- level of system components;
- operational level.

At level of PWEPI components ACS carries out optimum control by technical criteria of efficiency. Existence of operational level means, that effective work of independent PWEPI is only possible when of automatic control systems (ACS) is used.

The greatest interest represents operational level on which the optimum control is carried out on economic or other criterion of efficiency.

When the object of management is complex system, the approach to management in the ACS, based on management on interval parameters, is inadequate. In this case

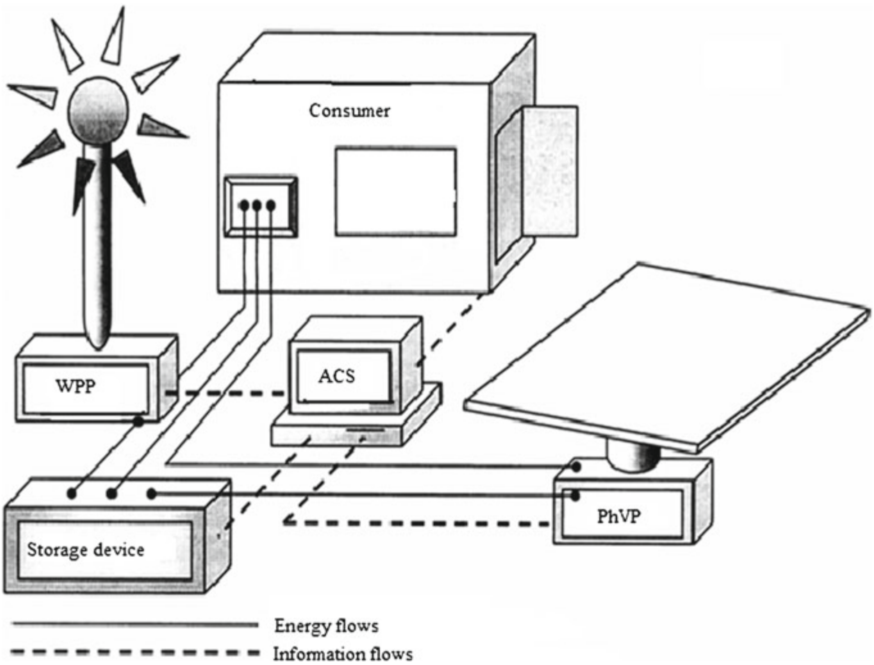


Fig. 48.7 Schematic diagram of the photo—wind plant

development of operating influence should be carried out on the basis of data about a current condition of the object. Generally the task of identification of a condition of object on the basis of the information on its current parameters represents a typical images recognition problem.

Synthesis SAC is spent taking into account analysis of PWEPI at two levels:

- level of power supply system components on which the optimum control task of separate devices is solved;
- operational level on which the task of optimum distribution of energy between consumers and the store is solved.

The goal of ACS consists in automatic maintenance of technology requirements of working capacity of components of a power supply system, reducing the probability of the accidents connected with undersupply of energy to the consumer. This purpose is reached by automatic maintenance of operation of power generator in a of the maximum power mode, automatic protection of devices emergency situations, coordination of operating of separate units in order to enforce a course of the electricity generation to predetermined normal mode.

Methods for optimization of the functioning of traditional power systems (PS), consuming RES, are now well developing. Optimization criteria are: the minimization of expenses for fuel supplied to the system, as well as the operating costs. In this case the load is distributed to consumers regardless of their optimum power and all calculations are performed for a given operating condition.

This approach is not acceptable for many reasons. Firstly, PWPI are usually unattended, therefore, operating costs can be almost neglected.Secondly, renewable energy sources (RES) initially do not have the costs. Thirdly, renewable energy converters are characterized by relatively high cost. Therefore, in this case the most complete maintenance of consumers by minimizing energy losses is best corresponds to economic optimum requirement.

Autonomous PWPI are characterized by higher cost of generated energy and the unevenness of its receipt. Therefore, the most effective system and method of operating control is system using energy storage for power excess.

Due to aforementioned features of the autonomous PWPI as a method of their control at the operational stage, it is advisable to adopt a combined approach with the accumulation of excess energy and distribution of load. In the conditions of the existing or predictable energy deficiency the load distribution is carried out based on their priority, and in the conditions of an excess of generated energy—its accumulation.

At the operational stage ACS is carried out operational control of the distribution of energy flows between the elements of the power grid by coordinating the operation of individual control devices on the first stage.

The goal of considered stage of ACS—the most complete and uninterrupted supply of electricity to consumers when it is irregular admission in the conditions of normal operating mode of all the elements of the power grid. Thus, the objective of SAC at the operational stage is dual: the most complete ensuring both current and future demands of consumers in electricity [5].

Therefore, the control system at this stage should have an optimum character. As an optimality criterion can be adopted level of reliability of power supply: a minimum of the time-averaged mathematical expectation of relative undersupply of energy to different groups of consumers considering the weight coefficients of these groups [5].

References

1. Baykov NM, Grinkevich RN (2009) The forecast of development of branches of power complex in the world and on the basic regions till 2030. Ph.D. thesis, The Russian Academy of Sciences
2. Michael TB (2003) Technology corridor: Reliability demands will drive automation//Fortnightly Magazine. http://www.fortnightly.com/fortnightly
3. Simankov VS, Lutsenko EV (1999) Adaptive management of difficult systems on the basis of the theory of images recognition. Kuban Technical, Krasnodar
4. Smart Grid – Future Power [electronic resource]. http://www.smartgrid.ru/smart-wiki/slovar/smart-grid/
5. Yager RR, Rybalov A (1997) Noncommutative self-identity aggregation. Fuzzy Sets Syst 85:73–82

Chapter 49
An Inexact Pricing Model for Tradable Water Pollution Emission Permit and Its Application in Chaohu Lake Watershed

Jingneng Ni, Fangqing Ding and Linsong Zhang

Abstract Water pollution emission permit trading system is an effective way to coordinate economic development and pollution control, is widely used. However, uncertainties and hierarchical management structures widely exist in the system, and play an important role. In this research, a triangular fuzzy random variable is employed to deal with the dual uncertainty with both fuzziness and randomness. The bi-level relationship in pricing for water pollution emission permit has been clarified, and then, an inexact bi-level pricing model for water pollution emission permit trading has been established based on this bi-level relationship. An algorithm named the fuzzy random simulation based nested genetic algorithm with dynamic mutation has been designed to solve the proposed model. The model was applied to an actual case, the impact of the pricing of water pollution emission permit on its trading and the impact mechanism have been discussed and analyzed. It was found that the higher the price of water emission permit, the less of it will be traded, and vice versa. Further, the upper boundary of pricing water pollutant j emission permit is $\frac{p_{ik}-C_{ik}-M_k}{EV(\bar{\tilde{E}}_{ijk})}$. Under the price-driven, industrial production within the watershed will migrate from the high-emission sub-regions to the low-emission sub-regions.

Keywords Water pollution emission permit · Permit pricing · Chaohu lake watershed · Inexact model · FRs-based NGA-DM

J. Ni (✉)
Faculty of Mathematics and Physics, Hefei University, Hefei 230601, People's Republic of China
e-mail: nijn@hfuu.edu.cn

F. Ding
Institute of Scientific Computing, Hefei University, Hefei 230601, People's Republic of China

L. Zhang
Mathematical Modeling Laboratory, Hefei University, Hefei 230601, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_49

49.1 Introduction

Economic development and water environmental protection are a worldwide watershed management problem [3, 6, 10]. To develop the watershed economy, local governments need to expand industrial production, which inevitably leads to an increase in waste water. The environmental carrying capacity, however, is limited, so when the total water pollutants exceed the upper bound of the carrying capacity, the watershed water environment is destroyed. The limitations of the environmental carrying capacity, therefore, mean that there is an inherent conflict between water environmental protection and economic development in watershed management [2, 3]. Water pollution emission permit trading is an effective method for coordinating this kind of conflict, in which, pricing for water pollution emission permit plays a key role.

In the geographical position, watershed is a relatively independent surface water system, is an ideal planning unit of water pollution permit trading. Quantitatively express the relationship between environmental carrying capacity, industrial production, water pollution emissions, watershed management and so on, is the key of the pricing for water pollution emission permit. Mathematical modelling techniques are effective quantitative description tools and have been widely used in various issues of watershed management [15, 17]. However, uncertainties and hierarchical management structures widely exist in pricing for water pollution emission permit, and play an important role. Therefore, to describe water pollution emission permit pricing in watershed scale, new mathematical model needs to be developed.

In this research, dual uncertainty in the pricing of water pollution emission permit is discovered and its processing method is designed. A bi-level management structure of water pollution emission permit pricing in a watershed scale has been investigated, and it will be used as a conceptual model in the modeling process of this paper. The trading mechanism and pricing principles of water pollution emission permit have been clarified. Which will be used as a basis for modelling. Then, an inexact bi-level pricing model for water pollution emission permit trading in watershed scale will be established.

It is difficult to solve a bi-level programming model [11]. Even in its simplest case, bi-level programming is an NP-hard problem [1]. Therefore, to solve a inexact bi-level programming with fuzzy random variables, as the model proposed in the paper. A new calculation method needs to be designed.

The rest of this paper was organized as follows. In Sect. 49.2, trading mechanism, pricing principles, uncertainty and its processing method were given. Then, the inexact bi-level pricing model for water pollution emission permit trading in watershed scale was established, and a new algorithm namely the FRs-Based NGA-DM algorithm was designed for solving the model in Sect. 49.3. In Sect. 49.4, the proposed model was applied to a practical watershed, and some practical application results were obtained. The paper was concluded in Sect. 49.5.

49.2 Problem Statements

In a watershed, rivers, streams and lakes constitute a relatively independent surface water system. Therefore, watershed is an ideal planning unit of water pollution permit trading. However, before modeling for watershed water pollution permit pricing, some key issues should be thoroughly investigated.

49.2.1 Trading Mechanism

Water environment, as a kind of public resources, local government is usually the agent of its management, plays a key role. Therefore, to clarify the management structure of the local government is one of the key issues of watershed water pollution permit pricing. It plays a decisive role in water pollution emission permit trading.

In a watershed, developing economy and protecting water environment is the dual task of local government. To accomplish this task, the local government allocates a certain amount of water pollution emission quota to each sub-region according to its environmental carrying capacity. Maximizing the economic benefits as the goal, sub-regions adjust its production plans in accordance with their industrial capacity, product margins and water pollution emission quota. If the water pollutant discharge of the sub-region is more than allocated emission quota, the sub-region will buy corresponding amount of the water pollution emission permit from trading market. Conversely, the sub-region will sell its surplus quota to obtain extra profits. Thus, the local government regulates industrial production within the watershed by pricing water pollution emission permit, and further, to achieve the purpose of water environmental protection and regional economic development. The complex trading mechanism is shown in Fig. 49.1.

49.2.2 Pricing Principles

It can be seen from the trading mechanism that, there is a bi-level relationship between the local government and sub-regions. The local government has the higher authority, so is the upper level decision maker, with a decision making objective of watershed water environment protection. It regulates the trading between the sub-regions within the watershed by pricing water pollution emission permit. Meanwhile, the local government allocates a certain amount of initial water pollution emission quota to each sub-region based on its environmental carrying capacity. In accordance with the transaction price established by the local government, each sub-region buys/sells water pollution emission permit to arrange its production. Therefore, the sub-regions within the watershed are the subordinates, the lower level decision makers. This bi-level relationship can be clearly depicted in Fig. 49.2.

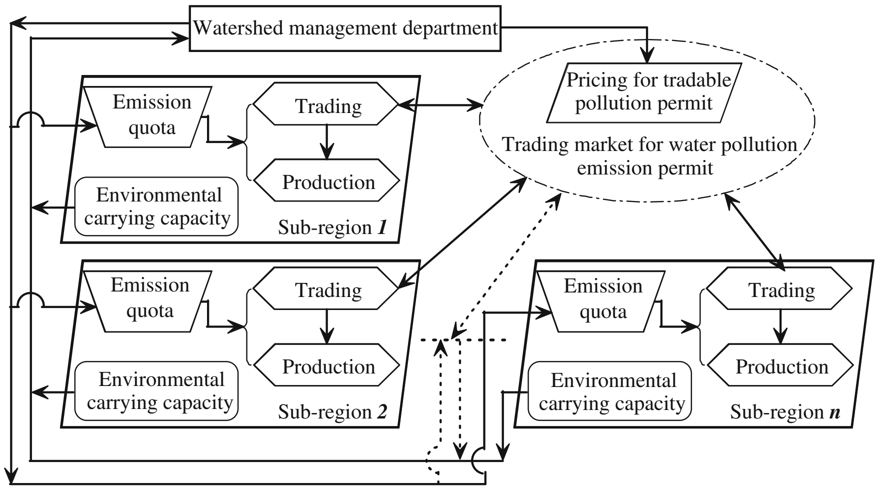


Fig. 49.1 Trading mechanism of water pollution emission permit in watershed scale

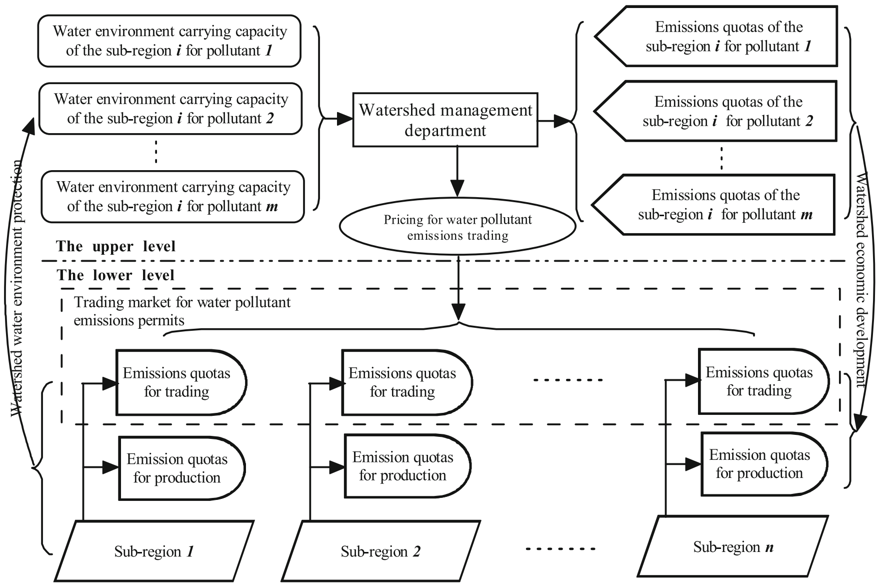


Fig. 49.2 The bi-level relationship in pricing of water pollution emission permit

The local government as an agent of watershed management, is responsible for the regional economic development and watershed water environment protection. When it setting the trading price of water pollution discharge permit, the following principles should be complied with:

- Fairness principle. That is, the pricing of water pollution emission permit should be able to promote the common development of all sub regional economy and the health of the whole watershed water environment.
- Environmental protection principle. In other words, "environmental protection first, economic development secondly" must be followed in pricing water pollution emission permit.
- Economic development principle. The pricing of water pollution discharge permit should have contributed to the growth of economy in the whole watershed.

49.2.3 Uncertainty and Its Processing Method

Uncertainty exists widely in the watershed management system [15]. In our research, pollutant discharge coefficient of unit product is uncertain. Affected by the quality of raw materials, processing technology, climate and other objective factors, the pollutant discharge coefficient of unit product is random uncertainty. In addition, in the production process, pollutant discharge coefficient of unit product is also affected by manual operation, production organization/management and other subjective factors, as a result, it also has fuzzy uncertainty. To deal with this kind of uncertainty with both randomness and fuzziness, is another key issue in pricing water pollution emission permit.

The fuzzy random variables proposed by [7, 8] can be used to deal with this kind of uncertainty. The processing method is as follows. Based on historical data, the current situation and expert professional knowledge, the pollutant discharge coefficient of unit product can be determined by an expert group E_n $(n = 1, 2, \ldots, N)$ in linguistic terms as an interval (i.e., $[a_n,\ c_n]$) with a most possible value (i.e., b_n), where N and E_n denote N different experts and the nth expert. Therefore, $\min_n\{a_n\}$ and $\max_n\{c_n\}$ are the lower and upper bounds of the pollutant discharge coefficient of unit product. By comparing the b_n obtained from N different experts, it can be found that b_n is a random variable (denoted $\bar{b}$) and approximately follows a normal distribution (i.e., $\bar{b} \sim N(\mu, \sigma^2)$), which can be estimated using a maximum likelihood method and justified using a chi-square goodness-of-fit test. From this, it can be deduced that the pollutant discharge coefficient of unit product fits the characteristics of fuzzy random variables proposed by [7, 8]. Therefore, the pollutant discharge coefficient of unit product can be described as a triangular fuzzy random variable $\tilde{\bar{x}}$, and $\tilde{\bar{x}} = (a, \bar{b}, c)$, where, $a = \min_n\{a_n\}$, $c = \max_n\{c_n\}$, $\bar{b} \sim N(\mu, \sigma^2)$. The entire process can be depicted as shown in Fig. 49.3.

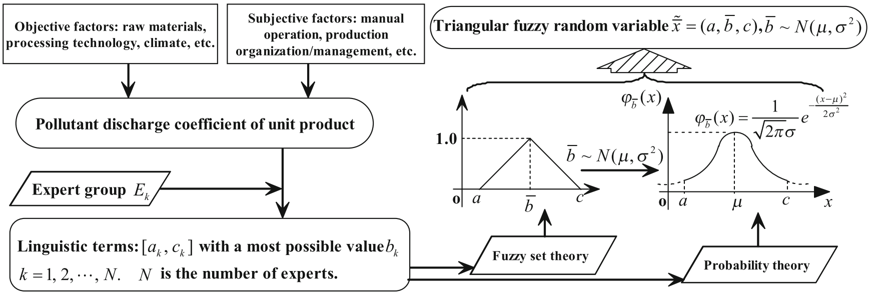


Fig. 49.3 Processing method of uncertainty

49.3 Modelling and Algorithm

From Sects. 49.2.1 and 49.2.2, Modelling for pricing of tradable water pollution emission permit is actually a bi-level optimization problem under fuzzy random environment. Thus, Fig. 49.2 can be used as a conceptual model for the modeling of this bi-level optimization problem. Then, an inexact pricing model for tradable water pollution emission permit in watershed scale can be gradually established.

49.3.1 Hypotheses and Symbols

Before modelling, some of the necessary hypotheses and symbols are pre-stated as follows.
(1) Hypotheses

- The study watershed is assumed to be a completely independent system, the inflow/outflow of water pollutants are not considered in the system, otherwise the established model need to increase parameters of the water pollutants inflow/outflow.
- Environmental carrying capacity of each sub-region within watershed is treated as an invariable constant. The changing of environmental carrying capacity caused by soil erosion, climate change, urbanization, etc., is not investigated in this research.
- For sub regions, water pollution emission quota are all used for production or trading, no third case.
- All sub-regions buy/sell water pollution discharge permit in strict accordance with the prices set by the local government. There is no unauthorized price increase/reduction phenomenon.
- The local government strictly follows the three pricing principles stated in Sect. 49.2.1, to set the water pollution discharge permit trading price

(2) Symbols and Its Explanations

i = sub-region index, $i = 1, 2, \ldots, I$, I is a positive integer;
j = water pollutant index, $j = 1, 2, 3, 4, 5$ denote water pollutant COD, NH_3-N, Petrol, VP and HM, respectively (COD = Chemical oxygen demand, NH_3-N = Ammonia nitrogen, Petrol = Petroleum, VP = Volatile phenols and HM = Heavy metal);
k = industrial product index, $k = 1, 2, \ldots, K$, K is a positive integer;
p_{ik} = the sales price of product k of sub-region i (10^4 RMB/t);
N_{ik} = the quantity of industrial product k in sub-region i (t);
C_{ik} = manufacturing costs per unit product k in sub-region i (10^4 RMB/t);
a_{ij} = pollutant j emission quota that the local government allocated to the sub-region i (t);
$\tilde{\bar{E}}_{ijk}$ = pollutant j emission coefficient of product k in sub-region i (kg/t), a fuzzy random variable;
N_{ik}^U = the upper production capacity limit of product k of sub-region $i(t)$;
M_k = the average profit of product k (10^4 RMB/t);
Q_j = the total watershed carrying capacity of water pollutant j (t);
x_j = the trading price of water pollutant j emission permit (10^4 RMB/t), the upper-level decision variables;
y_{ij} = the amount of water pollutant j emission permit that sub-region i bought/sold (t), the lower-level decision variables

49.3.2 Modelling for Pricing of Water Pollution Emission Permit

(1) Modelling for Sub-regional Trading

Each sub-region within the watershed organize its production to achieve the goal of the maximum profits. The profit of sub-region i is composed of three parts: product sales revenue, manufacturing cost, and trading income of water pollution emission permit. The product sales revenue is the sum of each kind of product sales price multiplied by the product quantity, i.e., $\sum_{k=1}^{K} p_{ik}N_{ik}$. Similarly, the manufacturing cost is $\sum_{k=1}^{K} C_{ik}N_{ik}$. The trading income of water pollution emission permit can be expressed as $\sum_{j=1}^{5} x_j y_{ij}$. Thus, the total profit of sub-region i can be written as

$$f(x_j, y_{ij}) = \sum_{k=1}^{K} p_{ik}N_{ik} - \sum_{k=1}^{K} C_{ik}N_{ik} + \sum_{j=1}^{5} x_j y_{ij}, \quad \forall i, \qquad (49.1)$$

where $f(x_j, y_{ij})$ denotes the total profit of sub-region i. It is a function of x_j and y_{ij}.

Water pollution discharge constraint of the sub-region i is that, for each water pollutant j, the total discharge of sub-region i should not exceed the sum of emission quota and trading emission permit. It can be written as

$$N_{ik}\tilde{\bar{E}}_{ijk} \lesssim a_{ij} - y_{ij}, \quad \forall i, j, \tag{49.2}$$

where $N_{ik}\tilde{\bar{E}}_{ijk}$ is a fuzzy random variable, but $a_{ij} - y_{ij}$ is a crisp variable, Therefore, $\lesssim$ is used to denote that a fuzzy random variable is not more than a crisp variable. In addition, "$-y_{ij}$" in Eq. (49.2) is consistent with "$+\sum_{j=1}^{5} x_j y_{ij}$" in Eq. (49.1). And, "$-y_{ij}$" denotes sub-region i sells y_{ij} water pollutant j emission permit.

Trading volume constraint for each sub-region, the total emission permit sold of sub-region i should not more than its emission quota. Thus, the trading volume constraint of sub-region i is obtained

$$a_{ij} - y_{ij} \geqslant 0, \forall i, j. \tag{49.3}$$

For each sub-region, each product production capacity is limited. Therefore, there is a production constraint as follows,

$$N_{ik} \leq N_{ik}^{U}, \forall i, k. \tag{49.4}$$

The constraint of production profit for sub-region. That is, when sub-region i buy y_{ij} emission permit to produce the product k, the profit it obtained should not be less than the average profit of product k. It can be described mathematically as

$$\frac{|y_{ij}| + y_{ij}}{2\tilde{\bar{E}}_{ijk}}(p_{ik} - C_{ik}) - x_j \frac{|y_{ij}| + y_{ij}}{2} \gtrsim \frac{|y_{ij}| + y_{ij}}{2\tilde{\bar{E}}_{ijk}} M_k, \forall i, k, \tag{49.5}$$

which can be succinctly rewritten as,

$$(p_{ik} - C_{ik}) - x_j\tilde{\bar{E}}_{ijk} \gtrsim M_k, \forall i, k. \tag{49.6}$$

In Eqs. (49.5) and (49.6), "$\gtrsim$" denotes the "not less" relationship of fuzzy random variable.

$\tilde{\bar{E}}_{ijk}$ in Eqs. (49.2) and (49.6) is a triangular fuzzy real variables. It makes the calculation of Eqs. (49.2) and (49.6) beyond the traditional mathematical method. Therefore, an expected value operator (EV) for the fuzzy random variable is employed to realize their calculation [14]. Thus, Eqs. (49.2) and (49.6) are converted to Eqs. (49.7) and (49.8), respectively.

$$EV(N_{ik}\tilde{\bar{E}}_{ijk}) \leqslant a_{ij} - y_{ij}, \forall i, j, \tag{49.7}$$

$$(p_{ik} - C_{ik}) - EV(x_j\tilde{\bar{E}}_{ijk}) \geqslant M_k, \forall i, k. \tag{49.8}$$

(2) Modelling for Watershed Management

The local government is an agent of watershed management, responsible for the regional economic development and watershed water environment protection.

Therefore, the three pricing principles stated in Sect. 49.2.2 are the basic guidelines for modelling watershed management.

To achieve this three pricing principles, the objective function of watershed management is designed to be the sum of three parts: the sum of each sub-regional actual emission and its environment carrying capacity ratio ($\sum_{i=1}^{I}\sum_{j=1}^{5}\frac{a_{ij}-y_{ij}}{a_{ij}} = \sum_{i=1}^{I}\sum_{j=1}^{5}(1-\frac{y_{ij}}{a_{ij}})$), the sum of the trading utility water pollutant j emission permit ($\sum_{i=1}^{I}\sum_{j=1}^{5}\sum_{k=1}^{K}\frac{|y_{ij}|}{\tilde{\tilde{E}}_{ijk}}$) and the sum of the profit generated in water pollution emission permit trading ($\sum_{i=1}^{I}\sum_{j=1}^{5}\sum_{k=1}^{K}\frac{|y_{ij}|+y_{ij}}{2\tilde{\tilde{E}}_{ijk}}(p_{ik}-C_{ik})+\frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{5}x_j|y_{ij}|$). The value of the first part is the smaller the better, while the value of the last two parts the larger the better. In order to make the three parts keep consistent, the last two parts are rewritten as $\sum_{i=1}^{I}\sum_{j=1}^{5}\sum_{k=1}^{K}\frac{\tilde{\tilde{E}}_{ijk}}{|y_{ij}|}$ and $\sum_{i=1}^{I}\sum_{j=1}^{5}\sum_{k=1}^{K}\frac{2\tilde{\tilde{E}}_{ijk}}{|y_{ij}|+y_{ij}}(p_{ik}-C_{ik})+\frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{5}\frac{1}{x_j|y_{ij}|}$ respectively. Thus, the objective function of watershed management can be written as

$$F(x_j, y_{ij}) = \sum_{i=1}^{I}\sum_{j=1}^{5}(1-\frac{y_{ij}}{a_{ij}}) + \sum_{i=1}^{I}\sum_{j=1}^{5}\sum_{k=1}^{K}\frac{\tilde{\tilde{E}}_{ijk}}{|y_{ij}|} + \sum_{i=1}^{I}\sum_{j=1}^{5}\sum_{k=1}^{K}\frac{2\tilde{\tilde{E}}_{ijk}}{|y_{ij}|+y_{ij}}(p_{ik}, -C_{ik}) + \frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{5}\frac{1}{x_j|y_{ij}|}, \tag{49.9}$$

where $F(x_j, y_{ij})$ denotes the objective function of the local government for watershed management, it is a function of x_j and y_{ij}. Furthermore, the Eq. (49.9) can be simplified rewritten as

$$F(x_j, y_{ij}) = \sum_{i=1}^{I}\sum_{j=1}^{5}\left[(1-\frac{y_{ij}}{a_{ij}}) + \sum_{k=1}^{K}\left(\frac{\tilde{\tilde{E}}_{ijk}}{|y_{ij}|} + \frac{2\tilde{\tilde{E}}_{ijk}(p_{ik}, -C_{ik})}{|y_{ij}|+y_{ij}}\right) + \frac{1}{2}\frac{1}{x_j|y_{ij}|}\right], \tag{49.10}$$

where $\tilde{\tilde{E}}_{ijk}$ in Eq. (49.10) is a triangular fuzzy random variable, therefore, a chance objective [13] is employed to perform the calculation. Under a probability ϑ and a possibility θ, the objective function $F(x_j, y_{ij})$ can be converted into a chance objective function, as follows,

$$F(x_j, y_{ij}) = Ch\left\{\sum_{i=1}^{I}\sum_{j=1}^{5}\left[(1-\frac{y_{ij}}{a_{ij}}) + \sum_{k=1}^{K}\left(\frac{\tilde{\tilde{E}}_{ijk}}{|y_{ij}|} + \frac{2\tilde{\tilde{E}}_{ijk}(p_{ik}-C_{ik})}{|y_{ij}|+y_{ij}}\right) + \frac{1}{2}\frac{1}{x_j|y_{ij}|}\right]\right\}(\vartheta, \theta). \tag{49.11}$$

Water pollution constraint for whole watershed, that is, the total emission of water pollutant j should not exceed the total carrying capacity of the whole watershed. It can be expressed mathematically as

$$\sum_{i=1}^{I}\sum_{k=1}^{K} N_{ik}\tilde{\overline{E}}_{ijk} \lesssim Q_j, \forall j. \tag{49.12}$$

Similar to Eqs. (49.2), (49.6) and (49.12) can be rewritten as Eq. (49.13) by using the expected value operator of fuzzy random variable.

$$EV\left(\sum_{i=1}^{I}\sum_{k=1}^{K} N_{ik}\tilde{\overline{E}}_{ijk}\right) \leq Q_j, \forall j. \tag{49.13}$$

Non-negative constraint for pricing of tradable water pollution emission permit, i.e., the price of tradable water pollution emission permit is not negative. Therefore,

$$x_j \geq 0, \forall j. \tag{49.14}$$

(3) Pricing Model of Water Pollution Emission Permit

According to the bi-level relationship in pricing for water pollution emission permit within a watershed (i.e., Fig. 49.2, and through integration Eqs. (49.1), (49.3), (49.4), (49.7), (49.8), (49.11)–(49.14)), an inexact bi-level pricing model for water pollution emission permit trading can be obtained as follows,

$$\begin{array}{l}
\min\limits_{x_j}\ F(x_j, y_{ij}) = Ch\left\{\sum\limits_{i=1}^{I}\sum\limits_{j=1}^{5}\left[(1-\frac{y_{ij}}{a_{ij}}) + \sum\limits_{k=1}^{K}\left(\frac{\tilde{\overline{E}}_{ijk}}{|y_{ij}|} + \frac{2\tilde{\overline{E}}_{ijk}(p_{ik}-C_{ik})}{|y_{ij}|+y_{ij}}\right) + \frac{1}{2}\frac{1}{x_j|y_{ij}|}\right]\right\}(\vartheta, \theta) \\
s.t.\left\{\begin{array}{l}
EV\left(\sum\limits_{i=1}^{I}\sum\limits_{k=1}^{K} N_{ik}\tilde{\overline{E}}_{ijk}\right) \leq Q_j \\
x_j \geq 0 \\
j = 1, 2, \ldots, 5, \\
\text{where, } y_{ij} \text{ is the solution from} \\
\max\limits_{y_{ij}} f(x_j, y_{ij}) = \sum\limits_{k=1}^{K} p_{ik}N_{ik} - \sum\limits_{k=1}^{K} C_{ik}N_{ik} + \sum\limits_{j=1}^{5} x_j y_{ij} \\
s.t.\left\{\begin{array}{l}
EV(N_{ik}\tilde{\overline{E}}_{ijk}) \leqslant a_{ij} - y_{ij} \\
p_{ik} - C_{ik} - EV(x_j\tilde{\overline{E}}_{ijk}) \geqslant M_k \\
a_{ij} - y_{ij} \geqslant 0 \\
N_{ik} \leq N_{ik}^{U} \\
i = 1, 2, \ldots, I, \quad I \in N^{+} \\
k = 1, 2, \ldots, K, \quad K \in N^{+}.
\end{array}\right.
\end{array}\right.
\end{array} \tag{49.15}$$

49.3.3 Algorithm Design

A bi-level programming is an NP-hard problem even in its simplest linear case [9]. Therefore, it is difficult to deal with bi-level programming with triangular fuzzy random variables, e.g., the Eq. (49.15).

Table 49.1 The process of fuzzy random simulation for chance objective

Input	Decision variables x_j, y_{ij}
Output	The minimum value of the chance objective function
Step 1	Set probability level $\vartheta = \vartheta_0$ and possibility level $\theta = \theta_0$
Step 2	Set $F^* = +\infty$, $T = 0$, $N = N_0$ (the number of cycles)
Step 3	Randomly generate independently random numbers ω from Ω according to the
	probability measure ϑ_0
Step 4	Produce fuzzy variable $\widetilde{E}_{ijk}(\omega)$ based on the structure of the fuzzy random variable $\widetilde{\widetilde{E}}_{ijK}$
Step 5	Randomly generate crisp number E_{ijk} from the θ_0-level set of the fuzzy variable $\widetilde{E}_{ijk}(\omega)$
Step 6	Compute the value $F = \sum_{i=1}^{I}\sum_{j=1}^{5}\left[(1-\frac{y_{ij}}{a_{ij}}) + \sum_{k=1}^{K}\left(\frac{E_{ijk}}{\lvert y_{ij}\rvert} + \frac{2E_{ijk}(p_{ik}-C_{ik})}{\lvert y_{ij}\rvert + y_{ij}}\right) + \frac{1}{2}\frac{1}{x_j\lvert y_{ij}\rvert}\right]$
Step 7	If $F^* > F$, replace F^* with F, go to Step 5; else, $T = T + 1$
Step 8	If $T < N$, go to Step 3
Step 9	Return the value of F^*

The genetic algorithm was initially developed by Holland in 1975 [4], and has been widely used in watershed management for different issues [5, 16]. In this paper, Fuzzy random simulation based nested genetic algorithm with dynamic mutation (FRs based NGA-DM) is designed to solve the Eq. (49.15).

The fuzzy random simulation method was introduced and has been applied in practice by many scholars [12, 14]. It has been proved to be an effective tool in handling functions which contain fuzzy random variables. In Eq. (49.15), the $\widetilde{\widetilde{E}}_{ijk}$ in chance objective function is a triangular fuzzy random variable. Therefore, the fuzzy random simulation for the chance objective function in Eq. (49.15) is designed, and the procedure can be summarized as shown in Table 49.1. Dynamic mutation operator is designed as, Randomly generate $P_m \in (0, 1)$, P_m is the probability of mutation operation. Generate a random number m from (0, 1) and the chromosome v_i^s is selected as a parent provided that $m < P_m$. Repeat the above process $N_{\text{pop-size}}$ times, then $P_m N_{\text{pop-size}}$ chromosomes are expected to be selected. Suppose that v_1^s is chosen as a parent, then a mutation operation on v_1^s will produce a child u_1^s as follows. Randomly select a mutation direction $d \in R^n$ and M is a sufficiently large positive number, check $v_1^s + Md$ using fuzzy random simulation. If it is feasible, then $u_1^s = v_1^s + Md$, otherwise set M as a random number between 0 and M until a feasible child is found or a given number of cycles are completed.

Based on the preparation described above, the fuzzy random simulation based nested genetic algorithm with dynamic mutation (FRs-based NGA-DM) can be designed. The algorithm process of FRs-based NGA-DM is shown in Table 49.2.

Table 49.2 The process of fuzzy random simulation based nested genetic algorithm with dynamic mutation

Input	Parameters $N_{\text{pop-size}}$, P_c
Output	The best chromosome
Step 1	Initialize $N^u_{\text{pop-size}}$ and $N^l_{\text{pop-size}}$ chromosomes for the upper and lower level
Step 2	Check the lower level chromosomes feasibility
Step 3	Compute the fitness of the lower level chromosome
Step 4	Select the lower level chromosomes by running the entropy-Boltzmann selection
Step 5	Update the lower level chromosomes using crossover and dynamic mutation operator
	and check the feasibility of the offspring
Step 6	Check the lower level termination condition, false, go to Step 4
Step 7	Compute the fitness of the upper level chromosome using fuzzy random simulation
Step 8	Select the upper level chromosomes by running the entropy-Boltzmann selection
Step 9	Update the upper level chromosomes using crossover and dynamic mutation operator
	and check the feasibility of the offspring using fuzzy random simulation
Step 10	Check the upper level termination condition, false, go to Step 8
Step 11	Return the best chromosome as the optimal solution

49.4 Case Study

49.4.1 Overview of the Study Watershed

Chaohu lake watershed is located in the east China, has an area of 13, 486 km^2, catchment population of 9.8 million. The water system and administrative divisions of Chaohu lake watershed are shown in Fig. 49.4.

In the past few decades, with continuing economic growth and accelerating urbanization, the deterioration of surface water bodies in Chaohu lake watershed has become more and more serious. In 2000, Chaohu lake watershed was listed in "water pollution prevention and control on the three rivers and three lakes" by the state environmental protection administration of China. Therefore, the optimization of regional economies, social politics and water quality protection is an essential task facing the local government of Chaohu lake watershed.

49.4.2 Data Acquisition and Model Results

As can be seen from Fig. 49.4, there are 9 sub-regions located in Chaohu lake watershed. Therefore, the sub-region index i value is 1, 2, . . . , 9, and it denote Hefei city, Luan city, Feixi county, Shucheng, Lujiang county, Wuwei county, Hanshan county, Chaohu city and Feidong county, respectively. There are three kinds of products

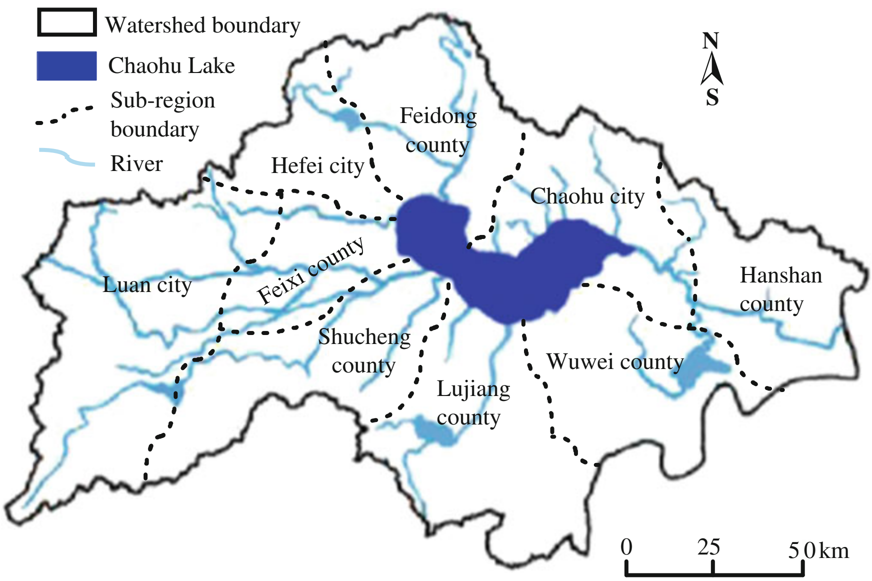


Fig. 49.4 The water system and administrative divisions of Chaohu lake watershed

we have been investigated in this study. Thus, the product index k value is $1, 2, 3$. The data of the model parameters were collected and collated by the authors from the Anhui Province Hydrology Bureau and Environmental Protection Office, Anhui Province Statistics Bureau, Chaohu Lake Administration Bureau and Anhui Province Inland Revenue Bureau, as listed in Tables 49.3, 49.4 and 49.5.

Based on the FRs-based NGA-DM algorithm process, the adopted parameters in the FRs-based NGA-DM parameter are set as follows: number of fuzzy random simulation draws $M = 100$; for both the upper and lower levels, population size $N_{\text{popsize}} = 20$, genetic probability $p_c = 0.3$ and the generation $= 500$. A computer program was developed to run Eq. (49.15) using Matlab software. The program was run on a Pentium 4, 2.40 GHz clock pulse with 1024 MB memory personal computer, and the calculation results for the model were obtained. When the average profit of product k are set as: $M_1 = 0.5$ and $M_2 = 0.6$ $M_3 = 0.45$ (10^4 RMB) respectively, the product production capacity set as infinity, i.e., $N_{ik}^U = +\infty$ for all $i = 1, 2, \ldots, 9$, $k = 1, 2, 3$, and the probability ϑ, possibility θ are set as $\vartheta = \theta = 0.85$. The optimal objective values and the optimal schemes were derived and are listed in Tables 49.6 and 49.7.

Table 49.3 Pollutant j emission per unit of product k in sub-region i, $\overline{\overline{E}}_{ijk}$ (kg/t)

i	j	$\overline{\overline{E}}_{ij1}$	$\overline{\overline{E}}_{ij2}$	$\overline{\overline{E}}_{ij3}$
1	1	$(15, \overline{E}_{111}, 29), \overline{E}_{111} \sim N(22, 3.9)$	$(9, \overline{E}_{112}, 15), \overline{E}_{112} \sim N(12, 3.3))$	–
	2	–	$(7, \overline{E}_{122}, 13), \overline{E}_{122} \sim N(10, 2.15))$	–
	3	–	–	$(1.2, \overline{E}_{133}, 3.6), \overline{E}_{133} \sim N(2.4, 0.11)$
	4	$(1.3, \overline{E}_{141}, 2.5), \overline{E}_{141} \sim N(1.9, 0.27)$	–	–
	5	–	–	$(0.2, \overline{E}_{153}, 0.6), \overline{E}_{153} \sim N(0.4, 0.09)$
2	1	$(17, \overline{E}_{211}, 33), \overline{E}_{211} \sim N(25, 4.7)$	$(13, \overline{E}_{212}, 19), \overline{E}_{212} \sim N(16, 4.3))$	–
	2	–	$(7, \overline{E}_{222}, 13), \overline{E}_{222} \sim N(10, 2.15))$	–
	3	–	–	$(1.1, \overline{E}_{233}, 3.7), \overline{E}_{233} \sim N(2.4, 0.13)$
	4	$(1.1, \overline{E}_{241}, 2.7), \overline{E}_{241} \sim N(1.9, 0.28)$	–	–
	5	–	–	$(0.1, \overline{E}_{253}, 0.7), \overline{E}_{253} \sim N(0.4, 0.11)$
3	1	$(16, \overline{E}_{311}, 32), \overline{E}_{311} \sim N(24, 4.3)$	$(11, \overline{E}_{312}, 19), \overline{E}_{312} \sim N(15, 4.4))$	–
	2	–	$(6, \overline{E}_{322}, 16), \overline{E}_{322} \sim N(11, 3.21))$	–
	3	–	–	$(1.2, \overline{E}_{333}, 3.4), \overline{E}_{333} \sim N(2.3, 0.09)$
	4	$(1.2, \overline{E}_{341}, 2.6), \overline{E}_{341} \sim N(1.9, 0.21)$	–	–
	5	–	–	$(0.1, \overline{E}_{353}, 0.5), \overline{E}_{353} \sim N(0.3, 0.07)$
4	1	$(17, \overline{E}_{411}, 35), \overline{E}_{411} \sim N(26, 4.5)$	$(13, \overline{E}_{412}, 19), \overline{E}_{412} \sim N(16, 4.1))$	–
	2	–	$(7, \overline{E}_{422}, 17), \overline{E}_{422} \sim N(12, 3.31))$	–
	3	–	–	$(1.4, \overline{E}_{433}, 3.8), \overline{E}_{433} \sim N(2.6, 0.13)$
	4	$(1.4, \overline{E}_{441}, 2.8), \overline{E}_{441} \sim N(2.1, 0.23)$	–	–
	5	–	–	$(0.2, \overline{E}_{453}, 0.8), \overline{E}_{453} \sim N(0.5, 0.09)$

(continued)

Table 49.3 (continued)

i	j	$\tilde{\tilde{E}}_{ij1}$	$\tilde{\tilde{E}}_{ij2}$	$\tilde{\tilde{E}}_{ij3}$
5	1	$(16, \overline{E}_{511}, 36), \overline{E}_{511} \sim N(26, 4.7)$	$(11, \overline{E}_{512}, 21), \overline{E}_{512} \sim N(16, 4.3))$	–
	2	–	$(8, \overline{E}_{522}, 20), \overline{E}_{522} \sim N(14, 3.53))$	–
	3	–	–	$(1.4, \overline{E}_{533}, 3.8), \overline{E}_{533} \sim N(2.6, 0.15)$
	4	$(1.5, \overline{E}_{541}, 3.1), \overline{E}_{541} \sim N(2.3, 0.25)$	–	–
	5	–	–	$(0.1, \overline{E}_{553}, 0.9), \overline{E}_{553} \sim N(0.5, 0.11)$
6	1	$(16, \overline{E}_{611}, 38), \overline{E}_{611} \sim N(27, 4.6)$	$(11, \overline{E}_{612}, 19), \overline{E}_{612} \sim N(15, 4.3))$	–
	2	–	$(9, \overline{E}_{622}, 17), \overline{E}_{622} \sim N(13, 3.22))$	–
	3	–	–	$(1.2, \overline{E}_{633}, 3.8), \overline{E}_{633} \sim N(2.5, 0.13)$
	4	$(1.2, \overline{E}_{641}, 3.0), \overline{E}_{641} \sim N(2.1, 0.21)$	–	–
	5	–	–	$(0.2, \overline{E}_{653}, 1.0), \overline{E}_{653} \sim N(0.6, 0.11)$
7	1	$(16, \overline{E}_{711}, 38), \overline{E}_{711} \sim N(27, 4.6)$	$(11, \overline{E}_{712}, 19), \overline{E}_{712} \sim N(15, 4.3))$	–
	2	–	$(8, \overline{E}_{722}, 16), \overline{E}_{722} \sim N(12, 3.11))$	–
	3	–	–	$(1.3, \overline{E}_{733}, 3.5), \overline{E}_{733} \sim N(2.4, 0.15)$
	4	$(1.2, \overline{E}_{741}, 3.2), \overline{E}_{741} \sim N(2.2, 0.23)$	–	–
	5	–	–	$(0.1, \overline{E}_{753}, 1.1), \overline{E}_{753} \sim N(0.6, 0.13)$
8	1	$(15, \overline{E}_{811}, 39), \overline{E}_{811} \sim N(27, 4.7)$	$(13, \overline{E}_{812}, 19), \overline{E}_{812} \sim N(16, 4.1))$	–
	2	–	$(12, \overline{E}_{822}, 16), \overline{E}_{822} \sim N(14, 3.19))$	–
	3	–	–	$(1.4, \overline{E}_{833}, 3.8), \overline{E}_{833} \sim N(2.6, 0.12)$
	4	$(1.1, \overline{E}_{841}, 3.1), \overline{E}_{841} \sim N(2.1, 0.23)$	–	–
	5	–	–	$(0.1, \overline{E}_{853}, 1.1), \overline{E}_{853} \sim N(0.6, 0.12)$

(continued)

Table 49.3 (continued)

i	j	$\tilde{\tilde{E}}_{ij1}$	$\tilde{\tilde{E}}_{ij2}$	$\tilde{\tilde{E}}_{ij3}$
9	1	$(16, \overline{E}_{911}, 38), \overline{E}_{911} \sim N(27, 4.6)$	$(11, \overline{E}_{912}, 19), \overline{E}_{912} \sim N(15, 4.3))$	–
	2	–	$(9, \overline{E}_{922}, 17), \overline{E}_{922} \sim N(13, 3.22))$	–
	3	–	–	$(1.2, \overline{E}_{933}, 3.8), \overline{E}_{933} \sim N(2.5, 0.13)$
	4	$(1.2, \overline{E}_{941}, 3.0), \overline{E}_{941} \sim N(2.1, 0.21)$	–	–
	5	–	–	$(0.2, \overline{E}_{953}, 1.0), \overline{E}_{953} \sim N(0.6, 0.11)$

Table 49.4 Pollutant j emission quota a_{ij} (10^5 t) and total pollutant j carrying capacity Q_j (10^5 t)

a_{ij}		$i =$									Q_j
		1	2	3	4	5	6	7	8	9	
$j =$	1	1.10	1.21	0.93	1.19	0.90	0.76	0.85	0.97	0.72	8.63
	2	0.23	0.11	0.08	0.13	0.11	0.07	0.09	0.14	0.10	1.06
	3	0.07	0.12	0.09	0.12	0.06	0.03	0.00	0.01	0.04	0.54
	4	0.06	0.09	0.03	0.01	0.02	0.00	0.02	0.04	0.00	0.27
	5	2.72	1.62	1.13	1.52	1.52	1.31	1.00	1.30	1.29	13.41

Table 49.5 The ith sub-regional product k sales price p_{ik} and manufacturing costs C_{ik} (10^4 RMB/t)

p_{ik}		$i =$								
		1	2	3	4	5	6	7	8	9
$k =$	1	5.82	5.53	5.84	5.68	5.78	5.89	5.65	5.55	5.73
	2	3.05	3.37	3.48	3.43	3.95	3.07	3.04	3.74	3.06
	3	7.24	7.10	7.26	7.22	7.10	7.44	7.16	7.11	7.20
C_{ik}		$i =$								
		1	2	3	4	5	6	7	8	9
$k =$	1	5.03	5.07	5.29	5.31	5.49	5.11	5.16	5.34	5.07
	2	2.51	2.98	2.74	2.79	2.61	2.63	2.57	2.98	2.92
	3	6.96	6.95	6.58	6.55	6.80	6.55	6.99	6.92	6.56

Table 49.6 The optimal objective values F^* and f_i^* (10^9 RMB)

F^*	f_1^*	f_2^*	f_3^*	f_4^*	f_5^*	f_6^*	f_7^*	f_8^*	f_9^*
0.843	4.35	2.723	1.621	0.971	0.887	0.389	0.922	3.102	0.533

Table 49.7 The optimal schemes y_{ij}^{*} (t) and x_{j}^{*} $(10^{4}RMB/t)$

y_{ij}^{*}		$i =$									x_{j}^{*}
		1	2	3	4	5	6	7	8	9	
$j =$	1	−0.9061	0.4692	−0.3841	0.8436	0.4764	−0.6475	−0.1886	0.8709	−0.5338	0.54
	2	−0.2300	0.4301	−0.0623	−0.0294	0.0626	−0.0980	−0.0722	0.0594	−0.0602	0.83
	3	0.1307	−0.0455	0.0602	−0.0096	−0.0493	−0.0109	0.0086	−0.0680	−0.0162	1.91
	4	0.0269	−0.0053	−0.0300	0.0035	0.0067	−0.0096	0.0036	−0.0024	0.0066	3.21
	5	2.6232	−1.4189	0.5337	−0.3908	−0.6207	−0.6131	0.3644	−0.3945	−0.0833	2.17

49.4.3 Discussion and Analysis

In Eq. (49.15), the constraint condition $EV(N_{ik}\tilde{\tilde{E}}_{ijk}) \leqslant a_{ij} - y_{ij}$ can be converted into $N_{ik} \leqslant \frac{a_{ij}-y_{ij}}{EV(\tilde{\tilde{E}}_{ijk})}$. Combining the objective function $\max_{y_{ij}} f(x_j, y_{ij}) = \sum_{k=1}^{K} p_{ik}N_{ik} - \sum_{k=1}^{K} C_{ik}N_{ik} + \sum_{j=1}^{5} x_j y_{ij}$, it can be obtained that $\max f(x_j, y_{ij}) = \sum_{k=1}^{K} \frac{(a_{ij}-y_{ij})(p_{ik}-C_{ik})}{EV(\tilde{\tilde{E}}_{ijk})} + \sum_{j=1}^{5} x_j y_{ij}$. Usually the price of the product is higher than its manufacturing cost, i.e., $(p_{ik} - C_{ik}) > 0$, thus, from $\sum_{k=1}^{K} \frac{(a_{ij}-y_{ij})(p_{ik}-C_{ik})}{EV(\tilde{\tilde{E}}_{ijk})} + \sum_{j=1}^{5} x_j y_{ij}$, it can be found that the higher the price of water emission permit, the less of it will be traded, and vice versa. Further, the upper limit of the price of water pollution emission permit can be derived from $p_{ik} - C_{ik} - EV(x_j\tilde{\tilde{E}}_{ijk}) \geqslant M_k$, that is, $x_j \leq \frac{p_{ik}-C_{ik}-M_k}{EV(\tilde{\tilde{E}}_{ijk})}$. If $x_j > \frac{p_{ik}-C_{ik}-M_k}{EV(\tilde{\tilde{E}}_{ijk})}$, the trading volume of water pollutant j emission permit is zero, i.e., $y_{ij} = 0$. Combined with the objective function of the upper level

$$\min F(x_j, y_{ij}) = \sum_{i=1}^{I}\sum_{j=1}^{5}\left[(1 - \frac{y_{ij}}{a_{ij}}) + \sum_{k=1}^{K}\left(\frac{\tilde{\tilde{E}}_{ijk}}{|y_{ij}|} + \frac{2\tilde{\tilde{E}}_{ijk}(p_{ik} - C_{ik})}{|y_{ij}| + y_{ij}}\right) + \frac{1}{2}\frac{1}{x_j|y_{ij}|}\right],$$

it can be found that, if $x_j > \frac{p_{ik}-C_{ik}-M_k}{EV(\tilde{\tilde{E}}_{ijk})}$, then $F(x_j, y_{ij}) = +\infty$. Obviously, it is the most undesirable case for the watershed managers. It is also from a opposite side stated: a reasonable pricing for water pollutant emission permit is necessary for watershed management.

When the probability ϑ and possibility θ of achieving the objective F are rising to $\vartheta = \theta = 0.90$, and other parameters remain unchanged. The optimal objective values and the optimal schemes can be obtained by running the Eq. (49.15), as listed in Table 49.8. Comparing the results listed in Tables 49.6, 49.7 and 49.8, it can be found that when the value of probability ϑ and possibility θ of achieving the objective F rising, the value of F and x_j will subsequently become larger, but the value of f_j will become smaller. It reveals the greater the probability and possibility to achieve the objective, the objective will be worse. In other words, the worse the goal, the easier to achieve. This is consistent with the actual situation. In addition, the analysis in previous paragraph obtain confirmed by the increase of the value of F and x_j.

The results in Tables 49.7 and 49.8 reveal an interesting phenomenon: in a reasonable pricing of water pollution emission permit, a cluster effect of industrial production will occur in a watershed. For instance, y_{11}^* and y_{12}^* in Tables 49.7 and 49.8 are negative, while y_{13}^*, y_{14}^* and y_{15}^* are positive. Referring to Table 49.3: Pollutant j emission per unit of product k in sub-region i $(\tilde{\tilde{E}}_{ijk})$, It can be found that, the production of product 2 will move out from the sub-region 1, the production of product 3 will be moved to sub-region 1, and the production of product 1 in sub-region 1 will be reduced. Throughout Tables 49.7 and 49.8, the results of the model reveal: for the production of the products, the production of product 1 will gather to sub-region 5, while, the production of product 2 will gather to sub-regions 2, 5 and 8,

Table 49.8 The model results under a probability and possibility $\vartheta = \theta = 0.90$

F^*		f_1^*	f_2^*	f_3^*	f_4^*	f_5^*	f_6^*	f_7^*	f_8^*	f_9^*
0.935		3.82	2.501	1.473	0.934	0.851	0.377	0.896	2.959	0.515
j	x_j	y_{1j}^*	y_{2j}^*	y_{3j}^*	y_{4j}^*	y_{5j}^*	y_{6j}^*	y_{7j}^*	y_{8j}^*	y_{9j}^*
1	0.59	−0.7958	0.3660	−0.2645	0.7180	0.3620	−0.5791	−0.1150	0.7653	−0.4568
2	0.91	−0.2173	0.3816	−0.0517	−0.0188	0.0528	−0.0859	−0.0598	0.0480	−0.0489
3	2.16	0.1201	−0.0350	0.0489	−0.0096	−0.0493	−0.0109	−0.0035	−0.0557	−0.0049
4	3.37	0.0260	−0.0041	−0.0288	0.0023	0.0055	−0.0085	0.0030	−0.0012	0.0059
5	2.42	2.4978	−1.4018	0.4168	−0.3172	−0.5740	−0.5026	0.2549	−0.2907	−0.0833

product 3 will gather to sub-regions 1 and 3; for the sub-regions, industrial production will mainly migrate from sub-regions 6 and 9 to sub-regions 1, 2, 5 and 8. That is, the industrial production in the watershed will migrate from the high-emission sub-regions to the low-emission sub-regions, to achieve minimize emission. This is the purpose of water pollution emission permit trading.

49.5 Conclusions

In this research, according to the actual fact that the uncertainty in pricing for water pollution emission permit is commonly caused by objective and subjective factors, triangular fuzzy random variable is employed as a tool to deal with this kind of uncertainty. An inexact bi-level pricing model for water pollution emission permit trading has been established based on the bi-level relationship in pricing for water pollution emission permit in a watershed. For solving the proposed model, the fuzzy random simulation based nested genetic algorithm with dynamic mutation algorithm has been designed. The last, the model was applied to an actual case: Chaohu lake watershed, China.

According to the actual case of the model application, the impact of the pricing of water pollution emission permit on its trading, and the impact mechanism have been discussed and analyzed. It is found that the higher the price of water emission permit, the less of it will be traded, and vice versa. Further, the upper boundary of pricing water pollutant j emission permit is $\frac{p_{ik}-C_{ik}-M_k}{EV(\tilde{\bar{E}}_{ijk})}$. In the price-driven, industrial production within the watershed will migrate from the high-emission sub-regions to the low-emission sub-regions, to achieve minimize emission and maximize economic benefits.

Acknowledgments This research is supported by the Applied Mathematics Key Construction Discipline of Hefei University (Grant No. 2014XK08), and also supported by the Natural Science Foundation of Anhui Province (Grant No. KJ2011B140). The authors thank the reviewers' valuable comments and editors' constructive suggestions, which will greatly improve the quality of this paper.

References

1. Bard JF (1991) Some properties of the bilevel programming problem. J Optim Theory Appl 68(2):371–378
2. Chen B, Chen GQ (2006) Ecological footprint accounting based on emergy: a case study of the Chinese society. Ecol Model 198:101–114
3. Dong XB, Yang WK et al (2012) The impact of human activities on natural capital and ecosystem services of natural pastures in North Xinjiang, China. Ecol Model 225:28–39
4. Holland JH (1975) Adaptation in natural and artificial systems. University of Michigan Press, Ann Arbor

5. Javidi SR, Zarghami M et al (2016) Application of risk-based multiple criteria decision analysis for selection of the best agricultural scenario for effective watershed management. J Environ Manag 168:260–272
6. Koundouri P, Rault KP et al (2015) Development of an integrated methodology for the sustainable environmental and socio-economic management of river ecosystems. In: science of the total environment http://dx.doi.org/10.1016/j.scitotenv.2015.07.082
7. Kwakernaak H (1978) Fuzzy random variables-I. Definitions and theorems. Inf Sci 15:1–29
8. Kwakernaak H (1979) Fuzzy random variables-II. Algorithms and examples for the discrete case. Inf Sci 17:253–278
9. Luis V, Savard G, Júdice J (1994) Descent approaches for quadratic bilevel programming. J Optim Theory Appl 81(2):379–399
10. Patterson T, Gulden T et al (2004) Integrating environmental, social and economic systems: a dynamic model of tourism in Dominica. Ecol Model 175:121–136
11. Vicente L, Savard G, Jdice J (1994) Descent approaches for quadratic bilevel programming. J Optim Theory Appl 81(2):379–399
12. Xu J, Song X et al (2015) GIS-modelling based coal-fired power plant site identification and selection. Appl Energy 159:520–539
13. Xu J, Yao L (2011) Random-like multiple objective decision making. Springer, Berlin
14. Xu J, Zhou X (2011) Fuzzy-like multiple objective decision making. Springer, Berlin
15. Yang P, Dong F et al (2016) A refined risk explicit interval linear programming approach for optimal watershed load reduction with objective constraint uncertainty tradeoff analysis. Front Environ Sci Eng doi:10.1007/s11783-014-0683-8
16. Zamani SH, Humbersona D et al (2016) Optimization of adaptive fuzzy logic controller using novel combined evolutionary algorithms, and its application in Diez Lagos flood controlling system, Southern New Mexico. Expert Syst Appl 43:154–164
17. Zhang H, Huang GH (2011) Assessment of non-point source pollution using a spatial multi-criteria analysis approach. Ecol Model 222:313–321

Chapter 50
QPSO-Based Location Selection of 10 kV Bench Transformer Distribution Center: Case Study in Guizhou Power Grid

Jiancheng Liu, Dun Xu, Ye Wang and Feng Li

Abstract This paper is based on the materials management of the power grid, through analyzing a range of materials management problems in the current Guizhou power grid, proposed the view that we can establish the distribution center, then it can meet the material needs of the power supply bureau at the same time try to reduce costs and focus on efficiency. After considering the various effects factors and the constraints, the QPSO-based location Selection model was given to solute the actual site selection problem in Guizhou power grid.

Keywords Site selection optimization · Quantum particle swarm · Guizhou power grid · 10 kV Bench transformer distribution center

50.1 Introduction

In terms of logistical system design and administration, distribution center location is a common problem faced by logistics managers. In recent years, increased production economies of scale and reduced transportation cost have focused attention on distribution center, which is viewed as the competency that links an enterprise with its customers and suppliers [3].

J. Liu
Logistics Services Center, Guizhou Power Grid co., LTD, Guiyang
550002, People's Republic of China

D. Xu (✉)
Institute of Emergency Management and Reconstruction in Post-disaster,
Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 253863444@qq.com

Y. Wang
Economic Management Institute, Guiyang University, Guiyang
550005, People's Republic of China

F. Li
Guizhou Huadian Power Generation Co. Ltd, Guiyang
550005, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_50

In order to reduce transportation cost, enforce operation efficiency and logistic performance, evaluating and selecting a suitable distribution center location has become one of the most important decision issues for distribution industries [1]. In the process of selection it is necessary first and foremost to identify the set of influential factors relevant to the distribution center location selection [2].

Many influential factors are considered for the selection of a particular plant location, e.g. investment cost, climate condition, labor force quality and quantity, transportation availability, etc. [8, 10]. Especially, in the power grid enterprise, distribution center is an extremely complex and tedious system, which included many complex practical considerations such as the transportation, business environment, labor force, policy and so on [6].

These factors can be classified into two categories: objective factors and subjective factors. Many precision-based methods for location selection have been developed. In this paper, we use the quantum particle swarm optimization method (QPSO) to deal them.

The evolutionary particle swarm optimization (PSO) is a global search strategy that can handle efficiently arbitrary optimization problems. In 1995, Kennedy and Eberhart introduced the PSO method for the first time [7]. Later, it received a considerable attention and proved to be capable of tackling difficult optimization problems. The basic idea of the PSO is to mimic the social interactions between members of biological swarms. One of the good examples illustrating the concept is the analogy with the swarm of bees. Solution candidates are allowed to fly in a specified field, looking for food. A quantum-inspired version of the PSO algorithm (QPSO) was proposed very recently [4, 9]. The QPSO algorithm permits all particles to have a quantum behavior instead of the classical Newtonian dynamics that was assumed so far in all versions of the PSO. Thus, instead of the Newtonian random walk, some sort of "quantum motion" is imposed in the search process. When the QPSO is tested against a set of bench marking functions, it demonstrated superior performance as compared to the classical PSO but under the condition of large population sizes [5]. One of the most attractive features of the new algorithm is the reduced number of control parameters. Strictly speaking, there is only one parameter required to be tuned in the QPSO.

50.2 Methodology

50.2.1 Key Problem Statement

The power grid can guarantee the development and safe operation based on the existing material management. However, there are still some insufficient. First, the bidding lacks of efficiency and accuracy. Second, the management of the suppliers are segmentary such as the supplies' quality, price, transportation, after-sales service and so on. Finally, there is no uniform warehouse management for 10 kV bench trans-

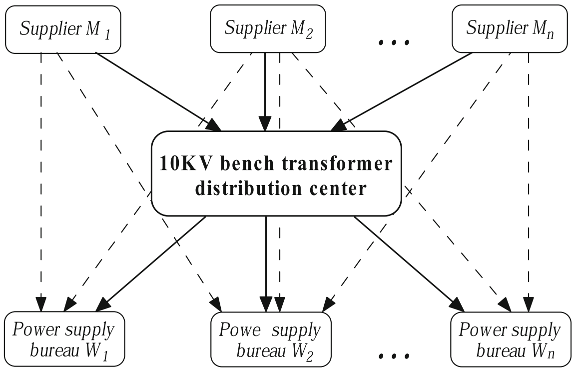


Fig. 50.1 The logistic system for the 10 kV bench transformer distribution

former materials in power supply bureaus. Therefore, according to the insufficient above, we need a standard distribution for the 10 kV bench transformer. As shown in the Fig. 50.1, we provide a distribution center for the distribution of the 10 kV bench transformer.

The location selection of 10 kV bench transformer distribution center is an extremely complex and tedious system, which included many complex practical considerations such as the transportation, business environment, labor force, policy and so on [6, 11]. The quantum particle swarm optimization model in this paper is aims to minimize the total cost of the distribution center. Therefore, some assumptions should be provided. First, each power supply bureau can direct import materials both from suppliers and the distribution center. And the selection principle of the supplies distribution is to minimize the total logistics cost. Second, the power supply bureau gets the material from the distribution center or suppliers is only related to the distance. Third, there is no capacity limitation in the distribution center, that is the supply is able to meet the demand. Finally, Storage costs and cargo backlog costs are ignored.

50.2.2 Model Formulation

(1) Notations

In order to facilitate the problem description,the following definitions are given.

- F: The total cost of supplies distribution system in the power grid company;
- C: The unit cost of storage in the distribution center;
- P: The types of materials;
- M: The numbers of suppliers;
- W: The numbers of power supply bureaus;
- U: A considerable positive number;
- fm: The capital cost of the distribution center;

g_k: The distance from the supplier k to the distribution center;
h_j: The distance from the distribution center to the power supply bureau j;
N_j: The count of the power supply bureau j gets emergency materials from the distribution center during a certain period;
N_{kj}: The count of emergency materials which the power supply bureau j gets from the supplier k during a certain period;
T_k: A decision variable about the relationship between the supplier k and the distribution center; 0, when they are not a supply and demand relationship; 1, otherwise;
K_j: A decision variable about the relationship between the power supply bureau j and the distribution center; 0, when they are not a supply and demand relationship; 1, otherwise;
G_k: The unit cost of transportation from the supplier k to the distribution center;
H_j: The unit cost of transportation from the distribution center to the power supply bureau j;
JH_j: The cost of transportation from the power supply bureau j to the distribution center in an emergency;
L_{kj}: The unit cost of transportation from the supplier k to the power supply bureau
l_{kj}: The distance from the supplier k to the power supply bureau j;
JL_{kj}: The cost of transportation from the supplier k to the power supply bureau j j; in an emergency;
X_{kp}: The numbers of material p which the distribution center gets from the supplier k during a certain period;
Y_{jp}: The numbers of material p which the power supply bureau j gets from the distribution center during a certain period;
Z_{kjp}: The number of material p which the power supply bureau j gets from the supplier k during a certain period;
S_{kp}: The material p supply capacity in the supplier k;
D_{jp}: The demand of material p in the power supply bureau j.

(2) Quantum particle swarm optimization model

The location selection of 10 kV bench transformer distribution center is to consider the minimum logistics cost for a period time, which should be composed of the following parts:

The transportation cost of X_{kp} from the supplier k to the distribution center:

$$\sum_{p=1}^{p} G_k X_{kp} g_k. \tag{50.1}$$

The transportation cost of Y_{jp} from the distribution center to the power supply bureau j:

$$\sum_{p=1}^{p} \sum_{j=1}^{W} H_j Y_{jp} h_j. \tag{50.2}$$

The cost of transportation from the distribution center to the power supply bureau j in an emergency:

$$\sum_{j=1}^{W} JH_j N_j h_j. \tag{50.3}$$

The transportation cost of Z_{kjp} from the supplier k to the power supply bureau j:

$$\sum_{j=1}^{W} \sum_{p=1}^{p} L_{kj} Z_{kjp} l_{kj}. \tag{50.4}$$

The cost of transportation from the supplier k to the power supply bureau j in an emergency:

$$\sum_{j=1}^{W} \sum_{k=1}^{M} L_{kj} N_{kj} l_{kj}. \tag{50.5}$$

The total cost of storage in the distribution center:

$$\sum_{p=1}^{p} C \sum_{j=1}^{W} Y_{jp}. \tag{50.6}$$

In conclusion, the cost model of the distribution center construction is given:

$$\begin{aligned} \min F = & \sum_{p=1}^{p} G_k X_{kp} g_k + \sum_{p=1}^{p} \sum_{j=1}^{W} H_j Y_{jp} h_j + \sum_{p=1}^{p} \sum_{j=1}^{W} Y_{jp} + fm \\ & + \sum_{j=1}^{W} \sum_{p=1}^{p} L_{kj} Z_{kjp} l_{kj} + \sum_{j=1}^{W} \sum_{k=1}^{M} L_{kj} N_{kj} l_{kj} + \sum_{j=1}^{W} JH_j N_j h_j. \end{aligned} \tag{50.7}$$

In the rectangular coordinate system, $X(x_0, y_0)$ reflected the distribution center, suppliers are denoted $M_k(x_k, y_k)(K = 1, 2, \ldots, M)$, and power supply bureaus are denoted $W_j(x_j, y_j)(j = 1, 2, \ldots, W)$. Therefore, the h_j and g_k in the above model are:

$$h_j = \sqrt{(x_j - x_0)^2 + (y_j - y_0)^2}, g_k = \sqrt{(x_k - x_0)^2 + (y_k - y_0)^2}. \tag{50.8}$$

The sum of the material p which the supplier k supply to the power supply bureau j and the distribution center should not more than its supply capacity:

$$\sum_{k=1}^{M} X_{kp} + \sum_{j=1}^{W} Z_{kjp} \leq S_{kp}. \tag{50.9}$$

The sum of the material p which the power supply bureau j gets form the supplier k and the distribution center should not less than its demand:

$$\sum_{j=1}^{W} Y_{jp} + \sum_{k=1}^{M} Z_{kjp} \geq D_{jp}. \tag{50.10}$$

The sum of the material p which the supplier k supply to the distribution center should not less than the numbers the the power supply bureau j gets form the distribution center:

$$\sum_{k=1}^{M} X_{kp} \geq \sum_{j=1}^{W} Y_{jp}. \tag{50.11}$$

50.2.3 Case Study

For the purpose of demonstrating the effectiveness of the proposed quantum particle swarm optimization model, in this section, a case study of Guizhou Power Grid is given.

The data is collected in the Guizhou Power Grid Corp, documents includes: Package summary table of 10 kV bench transformer, Standard sub table of 10 kV bench transformer, Purchasing management business guide of 10 kV bench transformer, Contract management business guide of 10 kV bench transformer. Table 50.1 is the summary of information about power supply bureaus, and Table 50.2 is summary of information about suppliers.

Step 1. Initialization algorithm parameters included population r,variable dimension D, inertial factor w, acceleration coefficient c_1 c_2 and iterations k.

Step 2. Random initialization the particle's position, which represents the distribution center, in the permitted range, and set up the initial speed $v_i^0 = 0$.

Step 3. Calculated the fitness value of each particle and set the P-best (personal best) coordinates of each particle to its current position. Then selected the best position from those P-bests which is the G-best (global best), and setted it to the current location of the best particles.

Step 4. Compared the fitness value and current P-best for each particle. If the fitness value is better than the current P-best,set it to the particle's position and update its P-best. In addition, if the P-best is better than the current G-best, set it to the particle's position and update the G-best.

Step 5. Computing the m-best, the random position PP_{ij} of each particle and updating their new positions according to the follow formulas:

$$M_{\text{best}} = \frac{1}{M}\sum_{i=1}^{M} P_i = \left(\frac{1}{M}\sum_{i=1}^{M} P_{i1}, \frac{1}{M}\sum_{i=1}^{M} P_{i2}, \ldots, \frac{1}{M}\sum_{i=1}^{M} P_{id}\right), \quad (50.12)$$

$$PP_{ij} = fp_{ij} + (1-f)p_{ij}, f = \text{rand}, \quad (50.13)$$

$$x_{ij} = PP_{ij} \pm \alpha|M_{\text{best}} - x_{ij}| \ln\left(\frac{1}{u}\right), u = \text{rand}. \quad (50.14)$$

The M-best are in the middle position of the particle swarm P-best; PP_{ij} is a random position between P_{ij} and P_{gj}, and α is a contraction and expansion coefficient which is an important parameter of QPSO.

Step 6. Verify the results whether satisfied the termination condition which are preset maximum number of iterations or minimum deviation request. if satisfied, stop the iteration and obtain the optimal solution Ps, otherwise go to step 2.

Table 50.1 Summary of information about power supply bureaus

The power supply bureau	W_1	W_2	W_3	W_4
The number of emergency (times/year)	2	2	3	1
Unit cost of transportation from the distribution center (yuan/ton × kilometer)	6	10	12	9
Demand for material P_1 (ton/year)	15	20	11	8
Demand for material P_2 (ton/year)	10	12	3	14
Demand for material P_3 (ton/year)	6	10	12	9
Distance to supplier M_1 (kilometer)	34.06	64.14	37.10	5.39
Distance to supplier M_2 (kilometer)	43.41	70.20	62.22	28.69
Distance to supplier M_3 (kilometer)	42.65	0.70	12.62	71.63
Unit cost of transportation from supplier M_1 (yuan/ton × kilometer)	5.5	4.6	7.8	3.1
Unit cost of transportation from supplier M_2 (yuan/ton × kilometer)	3.6	3.7	5.0	4.5
Unit cost of transportation from supplier M_3 (yuan/ton × kilometer)	3.7	6.8	5.9	4.5

Table 50.2 Summary of information about suppliers

The power supply bureau	M_1	M_2	M_3
Supply capacity for material P_1 (ton/year)	11	12	36
Supply capacity for material P_2 (ton/year)	18	27	15
Supply capacity for material P_3 (ton/year)	36	18	43
Unit cost of transportation from the distribution center (yuan/ton $\times$ kilometer)	36	18	43

Finally, according to the data in Tables 50.1 and 50.2, we obtain the optimal solution $x_0 = 0.35$, $y_0 = 3.75$, which means that the theoretical best location of power grid's distribution center should be selected in the 35 km north and 375 km west of the power supply bureau W_1. Then, according to the local geographical and other conditions, we find the feasible region which is the final location of the 10 kV bench transformer distribution center.

50.3 Conclusions

In this paper, we introduces the basic principles of 10 kV bench transformer distribution and the quantum particle swarm optimization. The key factors and constraints of the 10 kV bench transformer distribution center location were also be analyzed. And then, we provides a quantum particle swarm optimization model to solute the actual site selection problem in Guizhou power grid. This quantum particle swarm model integrated the intellectual factor of planners and the efficiency of computers efficiently, which both encouraged the initiative of planners and take advantage of the high precision or speed characteristics of computers.

References

1. Aikens CH (1985) Facility location models for distribution planning. Eur J Oper Res 22(3):263–279
2. Bowersox D (1996) Integrated supply chain process. Logist Manag 17–20
3. Chen CT (2001) A fuzzy approach to select the location of the distribution center. Fuzzy Sets Syst 118(1):65–73
4. Clerc M, Kennedy J (2002) The particle swarm-explosion, stability, and convergence in a multidimensional complex space. IEEE Trans Evol Comput 6(1):58–73
5. Eberhart RC, Shi Y (1998) Comparison between genetic algorithms and particle swarm optimization. In: Evolutionary Programming VII. Springer, Heidelberg, pp 611–616

6. Foxon TJ, Hammond GP, Pearson PJ (2010) Developing transition pathways for a low carbon electricity system in the UK. Technol Forecast Soc Change 77(8):1203–1213
7. Kennedy J (1997) The particle swarm: social adaptation of knowledge. In: IEEE International conference on evolutionary computation, IEEE, pp 303–308
8. Lin Y (2008) Research on the reform of electric power enterprise supplies management mode. Mod Bus Trade Ind 19(12):139–140
9. Yang S, Wang M, Jiao L (2004) A quantum particle swarm optimization. In: Congress on evolutionary computation CEC2004, vol 1. IEEE, pp 320–324
10. Zhang W, Zhao M (2006) The material management problem of modern electric power enterprise. Market Mod 11X:21–22
11. Zhou Q, Xiong X, Fang H (2015) Research on distribution center logistics equipment risk management. In: Proceedings of china modern logistics engineering. Springer, Heidelberg, pp 3–16

Chapter 51
An New Framework for MADM with Linguistic Information Under an IT2 FSs Environment

Lin Zhong, Xieyu Yang and Zhibin Wu

Abstract The main purpose of this paper is to propose a framework to deal with multi-attribute decision making (MADM) problems under an interval type-2 fuzzy set (IT2 FS) environment where the decision information is provided with linguistic variables. First, we determine the weights of each attributes using IT2 FSs. Then MAGDM procedure based on the α-based distance method and classical TOPSIS method under IT2 FSs environment is presented. In the framework, the linguistic decision information is represented by IT2 FSs. Finally, we apply the proposed MADM procedure to deal with a supplier selection problem to illustrate the practicality and effectiveness of the proposed method.

Keywords Supplier selection · TOPSIS · IT2 FSs · Distance measure

51.1 Introduction

A multiple attributes decision making (MADM) problem is a expert presents his testimony and finds the most suitable alternative among a finite set of projects based on a number of attributes. MADM has been widely applied to diverse fields [1]. In traditional decision-making problems, the preferences value expressed by the decision maker are precise numbers. Due to the fuzziness and uncertainty of decision-making problems and the inherent vagueness of human preferences, however, the best expression of decision-makers comes in natural language [2].

Traditionally, most linguistic terms are represented by type-1 fuzzy sets (T1 FSs). However, due to the inherent vagueness and uncertainty of human language, T1 FSs with crisp membership is not able to express it, adequately [3]. Unlike T1 FSs,

L. Zhong · Z. Wu (✉)
Uncertainty Decision-Making Laboratory, Sichuan University,
Chengdu 610064, People's Republic of China
e-mail: zhibinwu@scu.edu.cn

X. Yang
Business School, Sichuan University, Chengdu 610064, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_51

type-2 fuzzy sets (T2 FSs) employ membership functions that are also fuzzy, called a secondary membership function [4]. The T2 FSs are superior to T1 FSs because they can model second-order uncertainties [5]. When the secondary membership is constantly equal to 1, the T2 FS is called an interval type-2 fuzzy set (IT2 FS) [3, 4]. The computational complexity of IT2 FSs is simpler than T2 FSs, while they have the almost same ability in expressing uncertainty. Therefore, IT2 FSs are the most widely used type of T2 FSs [3].

Each alternative is evaluated with respect to each attribute based on decision maker's individual experience and judgement. In general, human decision-making process is subjective to a certain extent; which means decision maker acts and reacts based on their perceptions, not the objective reality [3]. Since individuals make decisions according to what they perceive to be reality, we should collect decision maker's opinion regarding the evaluations of the alternatives using a linguistic rating system or other data collection approaches [3]. IT2 FSs are able to efficiently express linguistic evaluations or assessments by objectively transforming them into numerical variables [6]. Thus, we applied the non-negative IT2 FSs to denote the subjective importance weights of various decision attributes.

Even though IT2 FSs have better uncertainty expressiveness, processing abilities and simpler computation, few studies have considered using IT2 FSs to represent the weights of attributes. This framework differs from the traditional method as the weights of attributes are expressed by IT2 FSs and the new IT2 FSs distance measure method is applied into TOPSIS to select the best alternative. Additionally, it is important to note that this framework is flexible enough to solve other complex decision making problems, such as strategic decision making and medical decision making.

The rest of the paper is organized as follows. In Sect. 51.2, the required background knowledge for IT2 FSs is introduced. In Sect. 51.3, a new framework to handle the MADM problems is presented. In Sect. 51.4, a practical decision-making example is given to illustrate the proposed methods. Conclusion is given in Sect. 51.5.

51.2 Preliminaries

In this section, we briefly review the basic concepts for IT2 FSs. As T1 FSs require a crisp membership function, IT2 FSs are able to express uncertainty by providing a measure of dispersion to better capture inherent uncertainties in a better way. It is especially useful in problems that is difficult to determine the exact membership function of a fuzzy set [4].

Definition 51.1 Let X be a universe of discourse, then a type-2 fuzzy set is defined as follows [4]:

$$\widetilde{A} = \left\{(x, u), u_{\widetilde{A}}(x, u) \mid x \in X, u \in J_x \subseteq [0, 1]\right\}, \tag{51.1}$$

where $0 \le u_{\widetilde{A}}(x, u) \le 1$ for each x and u. When the elements of the fuzzy numbers are continuous, the type-2 fuzzy set $\widetilde{A}$ is represented as follows:

$$\widetilde{A} = \int_{x\in X}\int_{u\subseteq J_x} u_{\widetilde{A}}(x,u)/(x,u) = \int_{x\in X}\left(\int_{u\subseteq J_x} u_{\widetilde{A}}(x,u)\Big/u\right)\Big/x, \quad (51.2)$$

where $\int\int$ denotes the union for all x and u, $J_x \subseteq [0, 1]$ is the primary membership of x in $\widetilde{A}$ and $\int_{u\subseteq J_x} u_{\widetilde{A}}(x,u)\diagup(x,u)$ indicates the secondary membership of $\widetilde{A}$. For discrete spaces, $\int$ is replaced by $\sum$.

Definition 51.2 Let $\widetilde{A}$ be a universe of discourse X, if all $u_{\widetilde{A}}(x, u) = 1$, then $\widetilde{A}$ is an interval type-2 fuzzy set (IT2 FS) and expressed as follows [4]:

$$\widetilde{A} = \int_{x\in X}\int_{u\subseteq J_x} 1/(x,u) = \int_{x\in X}\left(\int_{u\subseteq J_x} 1\Big/u\right)\Big/x. \quad (51.3)$$

Based on [7], we also defined the IT2 FS $\widetilde{A} = \left(\overline{\mu}_A(x), \underline{\mu}_A(x)\right)$ as a trapezoidal interval type-2 fuzzy set in the universe of discourse $X = [0, 1]$, as shown in Fig. 51.1, where $\widetilde{A}_i = \left(\left(a_{i1}^U, a_{i2}^U, a_{i3}^U, a_{i4}^U; H_{i1}^U, H_{i2}^U\right), \left(a_{i1}^L, a_{i2}^L, a_{i3}^L, a_{i4}^L; H_{i1}^L, H_{i2}^L\right)\right)$, and $0 \le a_{i1}^U \le a_{i2}^U \le a_{i3}^U \le a_{i4}^U \le 1, 0 \le H_{i1}^U \le H_{i2}^U \le 1, 0 \le a_{i1}^L \le a_{i2}^L \le a_{i3}^L \le a_{i4}^L \le 1, 0 \le H_{i1}^L \le H_{i2}^L \le 1$. Both of the $\overline{\mu}_{\widetilde{A}_i}(x)$ and $\underline{\mu}_{\widetilde{A}_i}(x)$ are type-1 fuzzy sets.

Definition 51.3 Suppose that there are two trapezoidal interval type-2 fuzzy sets $\widetilde{A}_1$ and $\widetilde{A}_2$ as follows [3]:

$$\widetilde{A}_1 = \left(\left(a_{11}^U, a_{12}^U, a_{13}^U, a_{14}^U; H_{11}^U, H_{12}^U\right), \left(a_{11}^L, a_{12}^L, a_{13}^L, a_{14}^L; H_{11}^L, H_{12}^L\right)\right), \quad (51.4)$$

$$\widetilde{A}_2 = \left(\left(a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U; H_{21}^U, H_{22}^U\right), \left(a_{21}^L, a_{22}^L, a_{23}^L, a_{24}^L; H_{21}^L, H_{22}^L\right)\right). \quad (51.5)$$

Then the arithmetic operations between them are defined as follows:

(1) Addition operation

$$\begin{aligned}\widetilde{A}_1 \oplus \widetilde{A}_2 &= \left(\overline{\mu}_{A_1}(x), \underline{\mu}_{A_1}(x)\right) + \left(\overline{\mu}_{A_2}(x), \underline{\mu}_{A_2}(x)\right)\\ &= \Big(\left(a_{11}^U + a_{21}^U, a_{12}^U + a_{22}^U, a_{13}^U + a_{23}^U, a_{14}^U + a_{24}^U; \min(H_{11}^U, H_{21}^U), \min(H_{12}^U, H_{22}^U)\right),\\ &\quad \left(a_{11}^L + a_{21}^L, a_{12}^L + a_{22}^L, a_{13}^L + a_{23}^L, a_{14}^L + a_{24}^L; \min(H_{11}^L, H_{21}^L), \min(H_{12}^L, H_{22}^L)\right)\Big).\end{aligned} \quad (51.6)$$

(2) Subtraction operation

$$\widetilde{A}_1 \Theta \widetilde{A}_2 = \left(\overline{\mu}_{A_1}(x), \underline{\mu}_{A_1}(x)\right) - \left(\overline{\mu}_{A_2}(x), \underline{\mu}_{A_2}(x)\right)$$
$$= \Big(\left(a_{11}^U - a_{21}^U, a_{12}^U - a_{22}^U, a_{13}^U - a_{23}^U, a_{14}^U - a_{24}^U; \min(H_{11}^U, H_{21}^U), \min(H_{12}^U, H_{22}^U)\right),$$
$$\left(a_{11}^L - a_{21}^L, a_{12}^L - a_{22}^L, a_{13}^L - a_{23}^L, a_{14}^L - a_{24}^L; \min(H_{11}^L, H_{21}^L), \min(H_{12}^L, H_{22}^L)\right) \Big). \tag{51.7}$$

(3) Multiplication operation

$$\widetilde{A}_1 \otimes \widetilde{A}_2 = \left(\overline{\mu}_{A_1}(x), \underline{\mu}_{A_1}(x)\right) \times \left(\overline{\mu}_{A_2}(x), \underline{\mu}_{A_2}(x)\right)$$
$$= \Big(\left(a_{11}^U \times a_{21}^U, a_{12}^U \times a_{22}^U, a_{13}^U \times a_{23}^U, a_{14}^U \times a_{24}^U; \min(H_{11}^U, H_{21}^U), \min(H_{12}^U, H_{22}^U)\right),$$
$$\left(a_{11}^L \times a_{21}^L, a_{12}^L \times a_{22}^L, a_{13}^L \times a_{23}^L, a_{14}^L \times a_{24}^L; \min(H_{11}^L, H_{21}^L), \min(H_{12}^L, H_{22}^L)\right) \Big). \tag{51.8}$$

(4) Division operation
($a_{21}^U, a_{22}^U, a_{23}^U, a_{24}^U, a_{21}^L, a_{22}^L, a_{23}^L$ and a_{24}^L are non-zero positive real numbers):

$$\widetilde{A}_1 \emptyset \widetilde{A}_2 = \left(\overline{\mu}_{A_1}(x), \underline{\mu}_{A_1}(x)\right) / \left(\overline{\mu}_{A_2}(x), \underline{\mu}_{A_2}(x)\right)$$
$$= \left[\left(\frac{a_{11}^U}{a_{21}^U}, \frac{a_{12}^U}{a_{22}^U}, \frac{a_{13}^U}{a_{23}^U}, \frac{a_{14}^U}{a_{24}^U}; \min(H_{12}^U, H_{22}^U) \right), \left(\frac{a_{11}^L}{a_{21}^L}, \frac{a_{12}^L}{a_{22}^L}, \frac{a_{13}^L}{a_{23}^L}, \frac{a_{14}^L}{a_{24}^L}; \min(H_{12}^L, H_{22}^L) \right) \right]. \tag{51.9}$$

(5) Multiplication by real number operation (k is a non-negative real number):

$$k \times \widetilde{A}_1 = \Big(\left(k \times a_{11}^U, k \times a_{12}^U, k \times a_{13}^U, k \times a_{14}^U; H_{11}^U, H_{12}^U\right),$$
$$\left(k \times a_{11}^L, k \times a_{12}^L, k \times a_{13}^L, k \times a_{14}^L; H_{11}^L, H_{12}^L\right) \Big). \tag{51.10}$$

Definition 51.4 The UMF and LMF of $\widetilde{A}_i$, which are shown in Fig. 51.1, can be represented in algebraic form as follows [8]:

$$\overline{\mu}_{\widetilde{A}_i}(x) = \begin{cases} \frac{H_{i1}^U}{a_{i2}^U - a_{i1}^U} x - \frac{H_{i1}^U a_{i1}^U}{a_{i2}^U - a_{i1}^U} & x \in [a_{i1}^U, a_{i2}^U]; \\ \frac{H_{i2}^U - H_{i1}^U}{a_{i3}^U - a_{i2}^U} x + H_{i1}^U - \frac{(H_{i2}^U - H_{i1}^U) a_{i2}^U}{a_{i3}^U - a_{i2}^U} & x \in [a_{i2}^U, a_{i3}^U]; \\ -\frac{H_{i2}^U}{a_{i4}^U - a_{i3}^U} x + \frac{H_{i2}^U a_{i4}^U}{a_{i4}^U - a_{i3}^U} & x \in [a_{i3}^U, a_{i4}^U]. \end{cases} \tag{51.11}$$

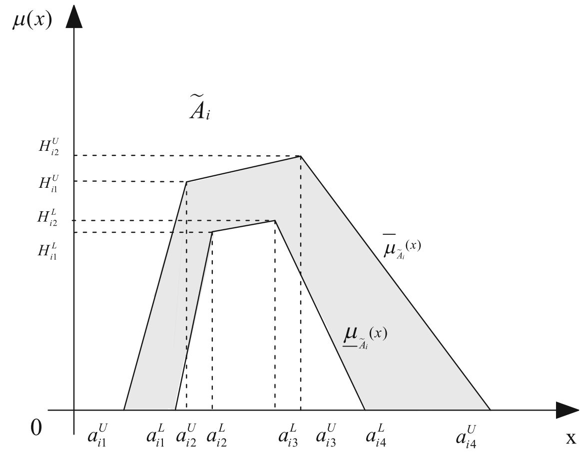


Fig. 51.1 The footprint of uncertainty (FOU) of interval type-2 fuzzy set $\widetilde{A}_i$

$$\underline{\mu}_{\widetilde{A}_i}(x) = \begin{cases} \frac{H_{i1}^L}{a_{i2}^L - a_{i1}^L} x - \frac{H_{i1}^L a_{i1}^L}{a_{i2}^L - a_{i1}^L} & x \in [a_{i1}^L, a_{i2}^L]; \\ \frac{H_{i2}^L - H_{i1}^L}{a_{i3}^L - a_{i2}^L} x + H_{i1}^L - \frac{(H_{i2}^L - H_{i1}^L) a_{i2}^L}{a_{i3}^L - a_{i2}^L} & x \in [a_{i2}^L, a_{i3}^L]; \\ -\frac{H_{i2}^L}{a_{i4}^L - a_{i3}^L} x + \frac{H_{i2}^L a_{i4}^L}{a_{i4}^L - a_{i3}^L} & x \in [a_{i3}^L, a_{i4}^L]. \end{cases} \tag{51.12}$$

The α-based distance, initially proposed by Figueroa-García et al. [9], is used to measure the distance between IT2 FSs.

Definition 51.5 Let $\widetilde{A}_1$ and $\widetilde{A}_2$ be non-negative IT2 FNs defined on X and $X \neq \{0\}$, the distance between them can be computed as follow:

$$d(\widetilde{A}_1, \widetilde{A}_2) \doteq \frac{1}{\Lambda} \sum_{i=1}^{n} x_i \left[\left| \overline{\mu}_{A_1}(x_i) - \overline{\mu}_{A_2}(x_i) \right| + \left| \underline{\mu}_{A_1}(x_i) - \underline{\mu}_{A_2}(x_i) \right| \right], \tag{51.13}$$

where $\Lambda = \sum_{i=1}^{n} x_i$.

If x is continuous and $x \in [0, 1]$, then $\Lambda = \int_0^1 x dx = \frac{1}{2}$, so d can be defined as:

$$d(\widetilde{A}_1, \widetilde{A}_2) \doteq 2 \int_0^1 x \left[\left| \overline{\mu}_{A_1}(x) - \overline{\mu}_{A_2}(x) \right| + \left| \underline{\mu}_{A_1}(x) - \underline{\mu}_{A_2}(x) \right| \right]. \tag{51.14}$$

51.3 Proposed Framework for MADM

As we all know, IT2 FSs can express the uncertainty of human language in a better way and have a simpler computation [10]. So we apply IT2 FSs to represent the linguistic terms in order to adequately illustrate the uncertainties in a complex situation. In this section, based on the α-based distance, we construct a new framework to deal with MADM problems under IT2 FSs environment.

In the proposed framework, the attributes weights are determined by the subjective judgements of decision makers. The ranking process is practiced based on the classical TOPSIS method, which has been developed by Hwang and Yoon [11] and also is a technique for order the preference by its similarity to the ideal points. These methods are discussed in detail in the following.

51.3.1 Interval Type-2 Fuzzy Representation

We assume that the decision maker D expresses his preferences of m alternatives $A_1, A_2 \ldots, A_m$ under n attributes $C_1, C_2 \ldots, C_n$. Firstly, the decision maker assesses all alternatives, and gives out the preferences of them. Then, a decision matrix $Y = (S_{ij})_{m\times n}$ is constructed under the linguistic terms set $S = (s_1, s_2, \ldots, s_l)$, where the linguistic term s_{ij} is the preference value for the A_i with respect to C_j given by D and $s_{ij} \in S$. After that, the linguistic information is translated into the IT2 FSs and each IT2 FS is normalized under the rule shown in Table 51.1. Finally, we obtain the normalized decision matrix $R_{ij} = (r_{ij})_{m\times n}$, shown as follows:

$$R = \begin{pmatrix} r_{11} & r_{12} & \ldots & r_{1n} \\ r_{21} & r_{22} & \ldots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \ldots & r_{mn} \end{pmatrix}, \tag{51.15}$$

where the parameter r_{ij} indicate the performance values of C_j with respect to A_i given by D, where $1 \leq i \leq m$; $1 \leq j \leq n$.

The decision maker first provides his judgements to express the subjective importance weights for various attributes based on the linguistic terms in Table 51.1.

Table 51.1 The weights evaluation linguistic terms and their corresponding IT2 FSs

Linguistic terms	Corresponding IT2 FNs
Unimportant (U)	((0.1,0.3,0.35,0.5;1,1), (0.2,0.25,0.3,0.4;0.9,0.9))
Medium unimportant (MU)	((0.35,0.5,0.6,0.7;1,1), (0.4,0.45,0.5,0.6;0.9,0.9))
Medium (M)	((0.5,0.7,0.8,0.9;1,1), (0.55,0.65,0.7,0.8;0.9,0.9))
Medium important (MI)	((0.7,0.9,0.95,1;1,1), (0.75,0.85,0.9,0.95;0.9,0.9))
Important (I)	((0.9,1,1,1;1,1), (0.95,1,1,1;0.9,0.9))

We translate the linguistic terms into IT2 FSs, and construct the vector as $(w_1, w_2, \ldots, w_j, \ldots, w_n)$, where $w_j = [w_j^L, w_j^U] = [(w_{1j}^L, w_{2j}^L, w_{3j}^L, w_{4j}^L; H_{1j}^L, H_{2j}^L)$, $(w_{1j}^U, w_{2j}^U, w_{3j}^U, w_{4j}^U; H_{1j}^U, H_{2j}^U)]$. The vector of attributes weights $\overline{W} = (\overline{w}_1, \overline{w}_2, \ldots, \overline{w}_j, \cdots, \overline{w}_n)$ is defined as following.

Definition 51.6 The attribute weight is a non-negative IT2 FS and obtained after normalizing process as follows:

$$\overline{w}_j = \frac{w_j}{w_1 + w_2 + \cdots + w_n}, \tag{51.16}$$

where

$$\begin{aligned}\overline{w}_j =& [\overline{w}_j^L, \overline{w}_j^U] \\ =& [(\overline{w}_{1j}^L, \overline{w}_{2j}^L, \overline{w}_{3j}^L, \overline{w}_{4j}^L; H_{1j}^L, H_{2j}^L), (\overline{w}_{1j}^U, \overline{w}_{2j}^U, \overline{w}_{3j}^U, \overline{w}_{4j}^U; H_{1j}^U, H_{2j}^U)];\end{aligned} \tag{51.17}$$

The sum of attributes weights has the following property:

$$\sum_{j=1}^{n} \overline{w}_j = [(1, 1, 1, 1; \min_{j=1}^{n} H_{1j}^L, \min_{j=1}^{n} H_{2j}^L), (1, 1, 1, 1; \min_{j=1}^{n} H_{1j}^U, \min_{j=1}^{n} H_{2j}^U)] \tag{51.18}$$

Proof $\sum_{j=1}^n \overline{w}_j = \sum_{j=1}^n \frac{w_j}{w_1+w_2+\cdots+w_n} = [(\sum_{j=1}^n \frac{w_{1j}^L}{w_{11}^L+w_{12}^L+\cdots+w_{1n}^L}, \sum_{j=1}^n \frac{w_{2j}^L}{w_{21}^L+w_{22}^L+\cdots+w_{2n}^L},$
$\sum_{j=1}^n \frac{w_{3j}^L}{w_{31}^L+w_{32}^L+\cdots+w_{3n}^L}, \sum_{j=1}^n \frac{w_{4j}^L}{w_{41}^L+w_{42}^L+\cdots+w_{4n}^L}; \min_{j=1}^n H_{1j}^L \min_{j=1}^n H_{2j}^L),$
$(\sum_{j=1}^n \frac{w_{1j}^U}{w_{11}^U+w_{12}^U+\cdots+w_{1n}^U}, \sum_{j=1}^n \frac{w_{2j}^U}{w_{21}^U+w_{22}^U+\cdots+w_{2n}^U}, \sum_{j=1}^n \frac{w_{3j}^U}{w_{31}^U+w_{32}^U+\cdots+w_{3n}^U}, \sum_{j=1}^n \frac{w_{4j}^U}{w_{41}^U+w_{42}^U+\cdots+w_{4n}^U};$
$\min_{j=1}^n H_{1j}^U, \min_{j=1}^n H_{2j}^U)] = [(1, 1, 1, 1; \min_{j=1}^n H_{1j}^L, \min_{j=1}^n H_{2j}^L),$

$(1, 1, 1, 1; \min_{j=1}^n H_{1j}^U, \min_{j=1}^n H_{2j}^U)]$.

51.3.2 The Ranking Process

The attributes weights obtained above are then applied to the TOPSIS method based on the α-based distance method to find the best alternative.

Based on the normalized decision matrix R, in which the alternative with a larger preference value is better, the positive ideal alternative A^+ is defined as follows:

$$A^+ = (r_1^+, r_2^+, \ldots, r_n^+), \tag{51.19}$$

and

$$\begin{aligned} r_j^+ = \max_i r_{ij} = &\Big(\big(\max_i r_{ij1}^U, \max_i r_{ij2}^U, \max_i r_{ij3}^U, \max_i r_{ij4}^U; \max_i H_{ij1}^U, \max_i H_{ij2}^U \big), \\ &\big(\max_i r_{ij1}^L, \max_i r_{ij2}^L, \max_i r_{ij3}^L, \max_i r_{ij4}^L; \max_i H_{ij1}^L, \max_i H_{ij2}^L \big) \Big) \\ = &\Big(\big(r_{j1}^{U+}, r_{j2}^{U+}, r_{j3}^{U+}, r_{j4}^{U+}; H_{j1}^{U+}, H_{j2}^{U+} \big), \\ &\big(r_{j1}^{L+}, r_{j2}^{L+}, r_{j3}^{L+}, r_{j4}^{L+}; H_{j1}^{L+}, H_{j2}^{L+} \big) \Big). \end{aligned} \tag{51.20}$$

The maximum primary variable is regarded as the best review among all alternatives and the maximum membership represents the least uncertainty.

The negative ideal alternative A^- is defined as follows:

$$A^- = (r_1^-, r_2^-, \ldots, r_n^-), \tag{51.21}$$

and

$$\begin{aligned} r_j^- = \min_i r_{ij} = &\Big(\big(\min_i r_{ij1}^U, \min_i r_{ij2}^U, \min_i r_{ij3}^U, \min_i r_{ij4}^U; \max_i H_{ij1}^U, \max_i H_{ij2}^U \big), \\ &\big(\min_i r_{ij1}^L, \min_i r_{ij2}^L, \min_i r_{ij3}^L, \min_i r_{ij4}^L; \max_i H_{ij1}^L, \max_i H_{ij2}^L \big) \Big) \\ = &\Big(\big(r_{j1}^{U-}, r_{j2}^{U-}, r_{j3}^{U-}, r_{j4}^{U-}; H_{j1}^{U-}, H_{j2}^{U-} \big), \\ &\big(r_{j1}^{L-}, r_{j2}^{L-}, r_{j3}^{L-}, r_{j4}^{L-}; H_{j1}^{L-}, H_{j2}^{L-} \big) \Big), \end{aligned} \tag{51.22}$$

in which the minimum primary variable represents the worst situation among m alternatives, and the maximum membership represents the least uncertainty.

We use the distance of each alternative from the ideal positive alternative to measure the goodness of each alternative and the distance is computed as follows:

$$\begin{aligned} RD^{i+} &= d\Big(\sum_{j=1}^{n} \overline{w}_j r_{ij}, \sum_{j=1}^{n} \overline{w}_j r_j^+\Big) = d(WR_i, WR^+) \\ &\doteq \frac{1}{\Lambda} \sum_{i=1}^{n} x_i \Big[\big| \overline{\mu}_{WR_i}(x_i) - \overline{\mu}_{WR^+}(x_i) \big| + \big| \underline{\mu}_{WR_i}(x_i) - \underline{\mu}_{WR^+}(x_i) \big| \Big], \end{aligned} \tag{51.23}$$

where $\Lambda = \sum_{i=1}^{n} x_i$.

We use the distance of each alternative from the ideal negative alternative to measure the negativity of each alternative and the distance is computed as follows:

$$\begin{aligned} RD^{i-} &= d(\sum_{j=1}^{n} \overline{w}_j r_{ij}, \sum_{j=1}^{n} \overline{w}_j r_j^-) = d(WR_i, WR^-) \\ &\doteq \frac{1}{\Lambda} \sum_{i=1}^{n} x_i \big[\big|\overline{\mu}_{WR_i}(x_i) - \overline{\mu}_{WR^-}(x_i)\big| + \big|\underline{\mu}_{WR_i}(x_i) - \underline{\mu}_{WR^-}(x_i)\big| \big], \end{aligned} \tag{51.24}$$

where $\Lambda = \sum_{i=1}^{n} x_i$.

In the end, we define the relative closeness to rank all alternatives. The relative closeness is defined as follows:

$$RV_i = \frac{RD^{i-}}{RD^{i+} + RD^{i-}}. \tag{51.25}$$

The better alternative is supposed to have the larger RV_i.

51.4 Illustrative Example

Supplier selection is one of the most important issues in supply chain management area. In this section, we apply the proposed framework to a numerical supplier selection example.

A transformer manufacturer, whose main production is the domestic transformer, intends to elect a befitting coil supplier. Five suppliers labelled as $\{A_1, A_2, A_3, A_4, A_5\}$ enter this competition. The leader has to evaluate those three suppliers and gives his preference under four criteria, which are Company reputation (C_1), Date of delivery (C_2), Price (C_3) and Quality (C_4). The leader should provide his decision matrix based on linguistic terms $s_1, s_2, s_3, s_4, s_5, s_6, s_7$, as shown in Table 51.2. The decision matrix is shown in Tables 51.3 and 51.4

- **Step 1**. Normalize the decision matrices. Since the price C_3 is cost benefit, we normalize the decision matrix with the complementary sets and translate linguistic terms into corresponding IT2 FSs, based on Table 51.2.
- **Step 2**. Calculate attributes weights. Based on Eqs. (51.16)–(51.18), we translate the linguistic terms into corresponding IT2 FSs and normalize them. Then the attributes weights are obtained as shown in Table 51.4.
- **Step 3**. Obtain the positive and negative ideal alternatives. Based on Eqs. (51.19)–(51.22), we find the positive and negative ideal alternatives as shown in Table 51.5.
- **Step 4**. Aggregate the decision matrix and the ideal points based on the attributes weights obtained in Step. 2. Then, calculate the α-based distance of each

Table 51.2 The linguistic terms and their corresponding IT2 FNs [7]

Linguistic terms	Corresponding IT2 FNs	Complementary linguistic terms
Very low (VL)	((0,0,0,0.1;1,1), (0,0,0,0.05;0.95,0.95))	VH
Low (L)	((0,0.1,0.15,0.3;1,1), (0.05,0.1,0.1,0.2;0.95,0.95))	H
Medium low (ML)	((0.15,0.3,0.35,0.5;1,1), (0.2,0.25,0.3,0.4;0.95,0.95))	MH
Medium (M)	((0.3,0.5,0.6,0.7;1,1), (0.4,0.45,0.5,0.6;0.95,0.95))	M
Medium high (MH)	((0.5,0.7,0.75,0.9;1,1), (0.6,0.65,0.7,0.8;0.95,0.95))	ML
High (H)	((0.7,0.9,0.95,1;1,1), (0.8,0.85,0.9,0.95;0.95,0.95))	L
Very high (VH)	((0.9,1,1,1;1,1), (0.95,1,1,1;0.95,0.95))	VL

Table 51.3 The decision matrix of leader

Decision makers	Alternatives	Criteria			
		C_1	C_2	C_3	C_4
D	A_1	M	VH	ML	H
	A_2	H	M	L	H
	A_3	M	MH	H	H
	A_4	MH	H	ML	MH
	A_5	H	VH	L	MH

aggregated alternative from the aggregated ideal alternatives, based on Eqs. (51.23)–(51.24), as shown in Table 51.6.

Step 5. Compute the ranking value of each alternative and obtain the ranking order of them. The ranking value of each alternative is shown in Table 51.7.

Finally, we obtain the ranking order of those five alternatives as $X_2 \succ X_4 \succ X_5 \succ X_1 \succ X_3$.

Table 51.4 The attributes weights decision matrix

Attributes	Weights linguistic terms	Weight of attribute
C_1	MI	((0.1786, 0.2000, 0.2162, 0.2308; 1, 1), (0.1833, 0.1940, 0.2000, 0.2162; 0.9, 0.9))
C_2	I	((0.2500, 0.2571, 0.2568, 0.2564; 1, 1), (0.2500, 0.2537, 0.2571, 0.2568; 0.9, 0.9))
C_3	VI	((0.3214, 0.2857, 0.2703, 0.2564; 1, 1), (0.3167, 0.2985, 0.2857, 0.2703; 0.9, 0.9))
C_4	I	((0.2500, 0.2571, 0.2568, 0.2564; 1, 1), (0.2500, 0.2537, 0.2571, 0.2568; 0.9, 0.9))

Table 51.5 The positive and negative ideal alternatives

Alternatives	Attributes	
$\widetilde{A}^+$	C_1	((0.7, 0.9, 0.95, 1; 1, 1), (0.8, 0.85, 0.9, 0.95; 0.95, 0.95))
	C_2	((0.9, 1, 1, 1; 1, 1), (0.95, 1, 1, 1; 0.95, 0.95))
	C_3	((0.7, 0.9, 0.95, 1; 1, 1), (0.8, 0.85, 0.9, 0.95; 0.95, 0.95))
	C_4	((0.7, 0.9, 0.95, 1; 1, 1), (0.8, 0.85, 0.9, 0.95; 0.95, 0.95))
$\widetilde{A}^-$	C_1	((0.3, 0.5, 0.6, 0.7; 1, 1), (0.4, 0.45, 0.5, 0.6; 0.95, 0.95))
	C_2	((0.3, 0.5, 0.6, 0.7; 1, 1), (0.4, 0.45, 0.5, 0.6; 0.95, 0.95))
	C_3	((0, 0.1, 0.15, 0.3; 1, 1), (0.05, 0.1, 0.1, 0.2; 0.95, 0.95))
	C_4	((0.5, 0.7, 0.75, 0.9; 1, 1), (0.6, 0.65, 0.7, 0.8; 0.95, 0.95))

Table 51.6 The Separation of each alternative from the ideal alternatives

Separations	Alternatives				
	X_1	X_2	X_3	X_4	X_5
RD^+	0.5199	0.2926	0.6635	0.5085	0.4820
RD^-	0.3923	0.4102	0.4645	0.4656	0.3904

Table 51.7 The relative closeness of each alternative

Separations	Alternatives				
	X_1	X_2	X_3	X_4	X_5
RV	0.4301	0.5837	0.4118	0.4779	0.4475

51.5 Conclusion

In this paper, we propose a framework to deal with multi-attribute decision making (MADM) problems under an interval type-2 fuzzy set (IT2 FS) environment where the decision information is provided with linguistic variables. Firstly, we define the non-negative IT2 FSs to represent subjective importance weights of attributes to avoid the information lost. Then, we apply the new IT2 FSs distance measure method, which is named α-based distance, into TOPSIS method to select the best alternative.

Acknowledgments This work was supported by National Natural Science Foundation of China (71301110) and the Humanities and Social Sciences Foundation of the Ministry of Education (3XJC630015) and also supported by Research Fund for the Doctoral Program of Higher Education of China (20130181120059) and supported by the Fundamental Research Funds for the Central Universities (skqy201525).

References

1. Kiliç M, Kaya I (2015) Investment project evaluation by a decision making methodology based on type-2 fuzzy sets. Appl Soft Comput 27:399–410
2. Wang JQ, Peng L, Zhang HY, Chen XH (2014) Method of multi-criteria group decision-making based on cloud aggregation operators with linguistic information. Inf Sci 274:177–191
3. Chen TY (2014) An ELECTRE-based outranking method for multiple criteria group decision making using interval type-2 fuzzy sets. Inf Sci 263:1–21
4. Mendel J (2007) Type-2 fuzzy sets and systems: an overview. IEEE Comput Intell Mag 2(1):20–29
5. Greenfield S, Chiclana F et al (2009) The collapsing method of defuzzification for discretised interval type-2 fuzzy sets. Inf Sci 179(13):2055–2069
6. Zhang Z, Zhang S (2013) A novel approach to multi-attribute group decision making based on trapezoidal interval type-2 fuzzy soft sets. Appl Math Model 36(7):4948–4971
7. Qin JD, Liu XW (2015) Multi-attribute group decision making using combined ranking value under interval type-2 fuzzy environment. Inf Sci 297:293–315
8. Xu J, Zhong L, Wu Z (2016) An ELECTRE I-based multi-criteria group decision making method with interval type-2 fuzzy numbers and its application to supplier selection. Technical report
9. Figueroa-García JC, Chalco-Cano Y, Román-Flores H (2015) Distance measure for Interval Type-2 fuzzy numbers. Discret Appl Math 197:93–102
10. Mendel J, Wu H (2007) Type-2 fuzzistics for nonsymmetric interval type-2 fuzzy sets: forward problems. IEEE Trans Fuzzy Syst 15(5):916–930
11. Hwang CL, Yoon K (1981) Multiple attribute decision making: methods and application. Springer, Berlin

Chapter 52
Located Multiple Depots and Vehicles Routing with Capacity Problem

Masoud Amel Monirian, Shabnam Mahmoudzadeh Vaziri and Asadollah Mahmoudzadeh Vaziri

Abstract Locating and routing problems are important issues in the world and many researchers have researched on this subject. But sometimes we should consider the problems together to solve them. In this paper, first we aim at locating some depots station in order to meet demand points (MeLRPC). According to high costs or inaccessibility to all points, the demand of limited points can meet. The second purpose is to determine optimal points that a vehicle should visit in its route, so that total distance of unvisited points from nearest covered point, reach its minimum amount. Unvisited points can refer to nearest station and supply their needs. In this paper we use simulated annealing algorithm to solve the model.

Keywords Locating-routing · Simulated annealing algorithm · Vehicles with limited capacity · Median tour

52.1 Introduction

The Location-routing problem is one of the major issues in today's world that in the last three decades has attracted a lot of attention to itself and recently many surveys are done about these problems [7, 8, 25]. In general, location-routing models want to find an appropriate number and location of service facilities and also determine the distribution routes and the movement of vehicles to reduce costs, simultaneously [21]. Thus, in the logistics discussion, this issue had has a special place in reducing costs and much attention is assigned to it.

M.A. Monirian (✉) · S.M. Vaziri
Faculty of Engineering, Industrial Engineering Department,
Ferdowsi University of Mashhad, Mashhad, Iran
e-mail: masoudmonirian@yahoo.com

A.M. Vaziri
Faculty of Mathematical Science and Statistics, Department of Mathematics,
University of Birjand, Birjand, Iran

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_52

Although most of these operational issues imply on the distribution of goods from the warehouse to customers, but cover some other efficient applications such as food distribution [32], newspapers distribution [12, 19], garbage collection [15], receipt delivery [17], military programs [22], package delivery [4, 31] and goods distribution for different customers [1].

The Location-routing has been constituted of two parts of placement (location) of facilities and vehicle routing. In other words, determining number of depots and finding the right places to build them on (FLP) and the allocation of appropriate routes to vehicles for acquiring demand of customers (VRP) is included in two separate problems which, LRP considers these two issues simultaneously to reduce costs, because the overall system costs will be very high if, locating these depots are made regardless of routing decisions. Considering that, both the VRP and FLP problems are NP-hard [5, 20], and LRP is also of the same type [33].

In transportation discussion, the problem is defined in another way, where a number of points have been covered and for demand estimation, vehicles have a tour, where a number of demand points are visited. The aim of these issues is minimization the entire tour duration and also, the sum of unvisited distances to the nearest point has been estimated. These problems are called median tour.

In general, we are looking to find a tour with a certain number of points in these kinds of problems [6].

In this paper, the new and applied model in the field of Location-routing are investigated in which vehicles have certain capacity and vehicle movement is in the form of a tour. The purpose of this paper is to minimize the total distance traveled between unvisited demand points and the nearest stations on the tour and minimize the total cost of the system. In other words, a number of demand points are existed that, the least possible warehouse between these points may be identified. Tours are considered in these warehouses for existed vehicles, so the distance from the nearest point on the tour and unmet demand points is minimized. Figure 52.1 illustrates this issue.

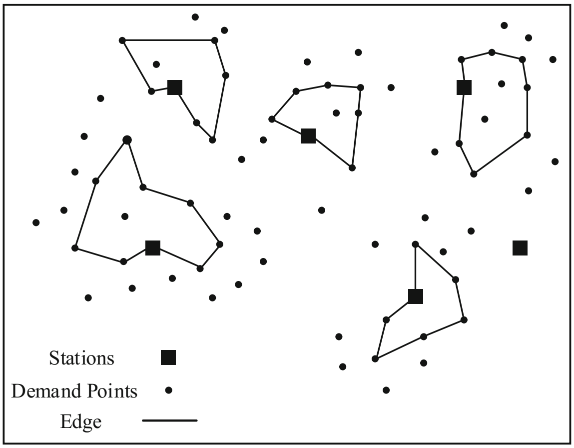


Fig. 52.1 Example of meeting demand in defined problem

In fact, median tour problem models have been used in objective function which have created a new feature and functionality for this problem. This model is important in the distribution of goods between customers, collecting letters from the mailbox and delivering to the post, unloading trash containers and etc. and, in practice it can reduce transportation costs and the allocation of places by taking the maximum possible and appropriate coverage, significantly.

The rest of this paper is organized as follows. In Sect. 52.2 we propose an overview of articles pertaining to this issue, we then explain mathematical model of the problem in Sect. 52.3, and finally the exact solution and solution using simulated annealing algorithm are expressed in Sect. 52.4. In Sect. 52.5 the computational results can be examined and some remarks are made in Sect. 52.6.

52.2 Literature Review

In the Location-Routing issue taking into account the limited capacity for vehicles or depots can add new constraints to LRP. Prince [23], presented a paper in which, given the limited capacity for routes and depots, have earned its solutions using tabu search methods. This limitation has been also considered in works of Belenguer [3] and Laporte [16] has been solved by methods including branch and cut (for the first problem). Other related article are [9, 10, 14].

Sometime in Routing problems, we should have pick-up and deliveries simultaneous. Mitsuo gen has been solved this problem by genetic algorithm [29]. In terms of the number of available vehicles (accessibility) and also their homogeneity, different studies can be done on the issue. For example, Caroline Prodhon [24] has considered limited number of homogeneous and similar vehicles in the depot set, While in some applications, such as models provided for handling hazardous waste, several kinds of vehicles have been used due to the differences in existing facilities (which exists for disposal or recycling of waste) and also various types of such waste. In this field Sibel Al Umur's article [2] can be noted. The first attempt was made in 1990 by Zografos and Samara [35] for these issues and was presented with the aim of reducing the traveled distances and the risks of handling and disposal of waste. Revell et al. [26] in 1991 and Stowers [28] in 1993, also expressed almost identical models, with the difference that Stowers is considered only minimizing the risk of location and routing model for the objective function. Several papers has been also provided in this respect.

The location-routing with capacity by [9] has been solved by meta-heuristic method. In the initial phase of solution, routes and their customers are all considered as a customer and convert to the facility location and allocation limits will be resolved by lagrangean relaxation. In the second phase, routes resulted from multi-depot vehicle routing problem are improved by the granular tabu search. At the end of each iteration, acquired data will be used for the next phase. This solution method in comparison with other innovative methods has better performance in different samples. Borges et al. [18] also proposed a hybrid genetic algorithm to solve the capacitated location-routing problem. We can mention articles such as [13, 30, 34] that use meta-heuristic methods to solve location-routing problem.

The multi-depot location-allocation problem with multiple vehicles and the limited number of vehicles for each type is divided to two sub-problem of vehicle Location-Routing and, each sub-problem is solved in sequential and iterative mode by simulated annealing algorithm.

There is another issue called Median Tour Problem (MTP) apart from LRP. In this problem, there is a tour that should only visit a limited number of nodes. The aim of solving this problem is finding a tour with the shortest length so that the total distance of nodes that are not on tour, and the closest station located on tour will be minimized. Among the applications of this problem we can mention the delivery systems of moving services, such as the delivery of health care services in rural areas of developing countries, hierarchical system of transport such as postal deliveries during the night and distributed computer networks. Objective function of this problem is similar to that proposed in Hakimi [11] as well ReVelle [27] that has been central facilities location.

According to studies in the field of LRP, considering the conditions of the MTP in its constraints, can be a new model in the field of placement and location. In this paper, to provide optimum solutions on issues such as placement of mailboxes or garbage collection system, these two problems (LRP and MTP) have been integrated with each other and, the depot placement and routing problem of vehicles with capacity is introduced starting from depots and return to them, with the aim of minimizing the traveled distance of unvisited demands to reach the nearest station on tour.

52.3 Mathematical Model

The parameters of the problem are defined as follows.

The graph $G = (V, E)$ is a directed network, so that V is a set of nodes, including subset of V_D (potential place of the depots) and the subset $V_C = V/V_D$ (customers set) and E is a set of edges connected between both members of V.

Each edge (i, j) have C_{ij} travel expenses, each depot $k \in V_D$ which only has a vehicle, capacity W_k and setup cost O_k and, each customer $i \in V_C$ has d_i demand that it should be supplied by a depot.

Other parameters in the model have been given below.

a_{ij}: the distance between i and j (each edge expense will be determined according to this parameter).

M: a large number.

Problem variables are also defines as follows:

U_{ijk}: auxiliary variables to eliminate sub-tour.

$$x_{ijk} = \begin{cases} 1 & \text{if vehicle } k \text{ go from point } i \text{ to } j \text{ (edge } ij \text{ in tour is related to depote } k\text{)}, \\ 0 & \text{otherwise.} \end{cases}$$

$$y_k = \begin{cases} 1 & \text{if depot is established at the point } k, \\ 0 & \text{otherwise.} \end{cases}$$

$$z_{ijk} = \begin{cases} 1 & \text{if } i\text{th customer is allocated to station } j \text{ located on } k\text{th depot}, \\ 0 & \text{otherwise.} \end{cases}$$

The objective function of this problem has been expressed to minimize the total weighted distance (depending on demand) of allocated points (similar to objective function of median problem) and minimize the total costs including depot setup fees and travel expenses on the tour. Given that, cost for each edge is defined based on the distance, standard of cost has been used in median objective function instead of the distance and, α coefficient has been used to display the difference between these two parameters.

The mathematical model of the problem is defined as follows:

$$\min \sum_{k \in V_D} O_k y_k + \sum_{k \in V_D} \sum_{j \in V} \sum_{i \in V} c_{ij} x_{ijk} + \alpha \times \sum_{k \in V_D} \sum_{j \in V_C} \sum_{i \in V_C} z_{ijk} d_i c_{ij}$$

$$\text{Subject to} \sum_{j \in V} x_{ijk} \leq y_k \,, \forall i \in V_C, \forall k \in V_D, \tag{52.1}$$

$$\sum_{j \in V_C} z_{ijk} \leq y_k, \forall i \in V_C, \forall k \in V_D, \tag{52.2}$$

$$z_{ijk} \leq \sum_{u \in V} x_{ujk}, \forall i \in V_C, \forall j \in V_C, \forall k \in V_D \text{ and } i \neq j, \tag{52.3}$$

$$\sum_{k \in V_D} \sum_{j \in V} x_{ijk} + \sum_{k \in V_D} \sum_{j \in V_C} z_{ijk} = 1, \forall i \in V_C, \tag{52.4}$$

$$\sum_{j \in V_C} x_{kjk} = y_k, \forall k \in V_D, \tag{52.5}$$

$$\sum_{j \in V_C} x_{kjk} = \sum_{i \in V_C} x_{ikk}, \forall k \in V_D, \tag{52.6}$$

$$\sum_{j \in V} x_{ijk} = \sum_{j \in V} x_{jik}, \forall i \in V, \forall k \in V_D, \tag{52.7}$$

$$\sum_{i \in V_C} u_{kik} = \sum_{i \in V_C} \sum_{j \in V} d_i x_{ijk}, \forall k \in V_D, \tag{52.8}$$

$$\sum_{i \in V} u_{ijk} = \sum_{i \in V} u_{jik} + d_j (\sum_{i \in V} x_{ijk}), \forall j \in V_C, \forall k \in V_D, \tag{52.9}$$

$$\sum_{j \in V_C} u_{ikk} = 0, \forall k \in V_D, \tag{52.10}$$

$$u_{ijk} \leq x_{ijk} \sum_{i \in V_C} d_i, \forall i \in V, \forall j \in V, \forall k \in V_D \text{ and } i \neq j, \tag{52.11}$$

$$\sum_{j\in V_C}\sum_{i\in V_C} d_i z_{ijk}+\sum_{j\in V}\sum_{i\in V_C} d_i x_{ijk} \le w_k y_k, \forall k \in V_D, \tag{52.12}$$

$$\sum_{j\in V} x_{ijk} + \sum_{j\in V} x_{jik} \le 1, \forall i \in V, \forall j \in V, \forall k \in V_D, \tag{52.13}$$

$$x_{ijk} \in \{1, 0\}, \forall i \in V, \forall j \in V, \forall k \in V_D, \tag{52.14}$$

$$y_k \in \{1, 0\}, \forall k \in V_D, \tag{52.15}$$

$$z_{ijk} \in \{1, 0\}, \forall i \in V, \forall j \in V, \forall k \in V_D, \tag{52.16}$$

$$u_{ijk} \ge 0, \forall i \in V, \forall j \in V, \forall k \in V_D. \tag{52.17}$$

In the first part of the objective function, the total cost (cost of setting up depot and travel expenses) is minimized in order to minimize the total length of the tour and in the second part, (according to demand) the total distance between points out tour and the stations are minimized to be allocated on the closest station on the tour. Constraints (52.1) and (52.2) guarantee that any customer or station allocate to just a path (which corresponds to a launched depot), and each of the points out of the tour is covered only by one station owned established depot. Constraint (52.3) states that the stations meet the demand points are located on the tour and, constraint (52.4) requires any point to be located on a tour or allocated to the stations on the tour. Constraint (52.5) is defined for depots and ensures that only one path is exited from each one. Constraints (52.6) and (52.7) also state that entry and exit of all routes specified on the depot, and each of created routes has continuity, and constraints (52.8) and (52.9) and (52.10) and (52.11) prevent the emergence of sub-tour in obtained solution. Constraint (52.12) is related to the maximum capacity of depots. Constraint (52.14) is intended for considering one-way paths and finally, constraints (52.14)–(52.17) show the range of variables changes.

52.4 Precise and Innovative Solutions

This problem has been solved using the CPLEX software, but due to high computational complexity and being NP-hard, the problem could not be solved in high dimensions at the right time, and also due to high computational time, less time is needed to solve with the exact solution. So the simulated annealing algorithm based on a single solution search has been used, which has been explained later.

52.4.1 Simulated Annealing Algorithm

Simulated annealing algorithm obtains optimal solution much more quickly and efficiently if it has an initial good solution. So, to get the initial answer, the following algorithm has been provided which, obtains the exact answer in some small issues. Steps to implement that algorithm is as follows:

Step 1. Allocation of each demand point to the nearest depot.
Step 2. Check capacity of each depot

- **Step 2.1**. Determine depots which, allocated demands exceeds its capacity;
- **Step 2.2**. Determine L numbers of the farthest points allocated to the specified depots (overload);
- **Step 2.3**. Choose point that capacity limitation is established by removing the demand of that point only;
  - **Step 2.3.1**. Check the distance L arranged points to the closest authorized depot (with capacity);
  - **Step 2.3.2**. Choose a point with the shortest distance to the next depot and allocation of this point to the nearest authorized depot and, return to step 2.2.

Step 3. Determine a TSP tour for each of depot (Clusters) using techniques such as nearest neighbor, multi-path, savings and so on.
Step 4. Convert any of the tours to the median tour problem.
Step 5. Remove the depot to reduce costs

- **Step 5.1**. determine depot with less than N points and remove them;
- **Step 5.2**. Comparison between costs of a depot establishment with allocation costs of points related to that depot with the other depots;
- **Step 5.3**. Allocation of points connected with removable depot to the nearest routed point which its depot has sufficient capacity.

Algorithmic process is described in Fig. 52.2.

It can be seen that the mentioned algorithm has been proposed in such a way that tries to minimize the costs of transport (route and allocation cost). In two other methods, depot setup fees mainly plays a big role in the objective function, is paying more attention.

Now using simulated annealing algorithm, we improve this answer that, steps of this algorithm is as follows.

Step 1. Answer has been turned into a one-dimensional array such that an index is considered for depots and demand points, and zero in this array is separator of covered points from the rest, so that the index that fall between two zero meet its demand and has been covered from the point before zero that is on the path. For example as shown in Fig. 52.3, given below of the points 4 and 5 are depots and the rest are demands, this array shows that the 5-1-3-5 route is formed and demand of point 2 is supplied by Point 1. Depo-4 has not yet been established.

Step 2. Then, one of the following searches is selected with a specified probability to improve:

Fig. 52.2 Initial flowchart

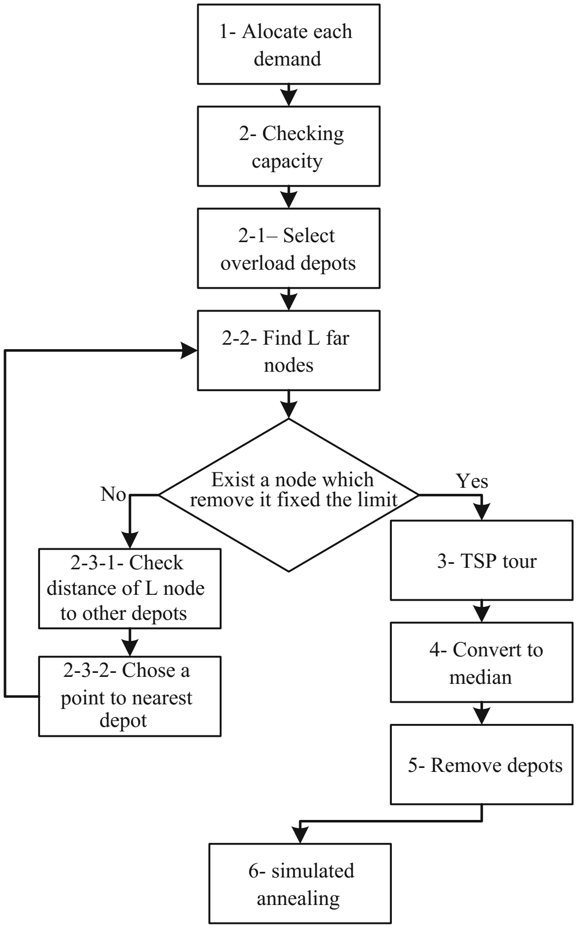
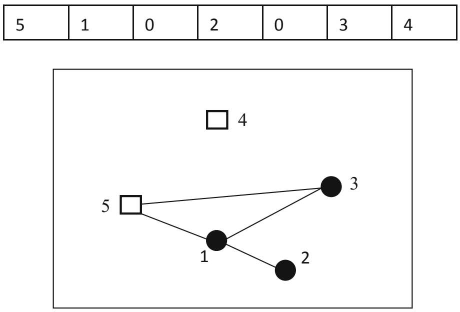


Fig. 52.3 An example



Step 2.1. Move up the index in the two cell arrays randomly;
Step 2.2. Pick a random cell and put it in place before another random cell;
Step 2.3. Add a zero to the array in random place to increase the points covered.

Step 3. Finally, by reaching the stopped final temperature, the best answer will be derived.

In all steps of this algorithm, feasibility condition of the answer is considered.

Following the implementation of this algorithm on examples in different dimensions and comparison of these answers with the exact solution will be done.

52.5 Computational Results

First, several problems with different dimensions is provided by using logic random numbers to solve. In the following table, dimensions of generated samples have been displayed in Table 52.1.

Considered range of data for the problem have been shown in Table 52.2. The proposed algorithm is implemented in Visual C ++ 2010, and all of the problems have been implemented on the PC with the profile of Core i5 “2.4” GHz Pentium and “4” GB RAM, equipped with operating system Windows “7”. CPLEX have also been implemented in the Visual 2010 so, results in Table 52.3 have been achieved.

In problem No. 5, due to the high volume of problem and algorithm computing, the exact solution could not solve the problem but heuristic algorithm solved it at

Table 52.1 Initial data

Number of customers	Number of depots	Number
12	4	1
13	4	2
14	4	3
15	5	4
40	10	5

Table 52.2 Problem’s data

Input of problem	Minimum amount	Maximum amount
Setting cost of depot	7142 $	12857 $
Travelling cost of path	1 $	18 $
Demand	50	200
Capacity of depot	800	950

Table 52.3 Results

Number of problem	Exact solution		Innovative solution		Gap %
	Execution time (minute)	Best answer (1000 units)	Execution time (minute)	Best answer (1000 units)	
1	1.44	60002	0.13	60002	0.142
2	2.07	90005	0.135	90198	0.214
3	1.98	95004	0.37	96106	1.16
4	4.45	96195	0.47	100725	11.13
5	–	–	2.34	245000	–

the right time and provided a good answer. According to the results, we have the solution algorithm provided with low gap and appropriate solution time of MeLRPC problem and also, it can be used for larger problems.

52.6 Conclusion

In this paper we proposed the mathematical model that considered Location - routing problem and median tour together. This model is applicable in real world issues such as postman problem, garbage collection and etc. As the problem has complexity we presented simulated annealing algorithm for solving the problem in reasonable time. Demand, in our work, is a deterministic parameter however in real world, demand contains uncertainty so for future works authors can deal with uncertainty in demand. According to traffic and staffs working hour authors can consider the model with time window constraints.

Acknowledgments The authors would like to acknowledge Professor Mitsuo Gen for his scientific support.

References

1. Aksen D, Altinkemer K (2008) A location-routing problem for the conversion to the "click-and-mortar" retailing: the static case. Eur J Oper Res 186(2):554–575
2. Alumur S, Kara BY (2007) A new model for the hazardous waste location-routing problem. Comput Oper Res 34(5):1406–1423
3. Belenguer JM, Benavent E et al (2011) A branch-and-cut method for the capacitated location-routing problem. Comput Oper Res 38(6):931–941
4. Bruns A, Klose A, Stähly P (2000) Restructuring of swiss parcel delivery services. OR Spectr 22(2):285–302
5. Cordeau JF, Laporte G et al (2006) Vehicle routing. Transp, Handb Oper Res Manag Sci 14:367–428

6. Current JR, Schilling DA (1994) The median tour and maximal covering tour problems: formulations and heuristics. Eur J Oper Res 73(1):114–126
7. Drexl M, Schneider M (2013) A survey of location-routing problems. Technical report, Darmstadt Technical University, Department of Business Administration, Economics and Law, Institute for Business Studies (BWL)
8. Drexl M, Schneider M (2015) A survey of variants and extensions of the location-routing problem. Eur J Oper Res 241(2):283–308
9. Duhamel C, Lacomme P et al (2010) A grasp × els approach for the capacitated location-routing problem. Comput Oper Res 37(11):1912–1923
10. El-Sherbeny NA (2010) Vehicle routing with time windows: an overview of exact, heuristic and metaheuristic methods. J King Saud Univ-Sci 22(3):123–131
11. Hakimi SL (1964) Optimum locations of switching centers and the absolute centers and medians of a graph. Oper Res 12(3):450–459
12. Jacobsen SK, Madsen OB (1980) A comparative study of heuristics for a two-level routing-location problem. Eur J Oper Res 5(6):378–387
13. Karaoglan I, Altiparmak F (2015) A memetic algorithm for the capacitated location-routing problem with mixed backhauls. Comput Oper Res 55:200–216
14. Karaoglan I, Altiparmak F et al (2011) A branch and cut algorithm for the location-routing problem with simultaneous pickup and delivery. Eur J Oper Res 211(2):318–332
15. Kulcar T (1996) Optimizing solid waste collection in Brussels. Eur J Oper Res 90(1):71–77
16. Laporte G, Nobert Y, Arpin D (1986) An exact algorithm for solving a capacitated location-routing problem. Ann Oper Res 6(9):291–310
17. Lin C, Chow C, Chen A (2002) A location-routing-loading problem for bill delivery services. Comput Ind Eng 43(1):5–25
18. Lopes RB, Ferreira C, Santos BS (2016) A simple and effective evolutionary algorithm for the capacitated location-routing problem. Comput Oper Res 70:155–162
19. Madsen OB (1983) Methods for solving combined two level location-routing problems of realistic dimensions. Eur J Oper Res 12(3):295–301
20. Megiddo N, Supowit KJ (1984) On the complexity of some common geometric location problems. SIAM J Comput 13(1):182–196
21. Min H, Jayaraman V, Srivastava R (1998) Combined location-routing problems: a synthesis and future research directions. Eur J Oper Res 108(1):1–15
22. Murty KG, Djang PA (1999) The US army national guard's mobile training simulators location and routing problem. Oper Res 47(2):175–182
23. Prins C, Prodhon C et al (2007) Solving the capacitated location-routing problem by a cooperative lagrangean relaxation-granular tabu search heuristic. Transp Sci 41(4):470–483
24. Prodhon C (2011) A hybrid evolutionary algorithm for the periodic location-routing problem. Eur J Oper Res 210(2):204–212
25. Prodhon C, Prins C (2014) A survey of recent research on location-routing problems. Eur J Oper Res 238(1):1–17
26. ReVelle C, Cohon J, Shobrys D (1991) Simultaneous siting and routing in the disposal of hazardous wastes. Transp Sci 25(2):138–145
27. ReVelle CS, Swain RW (1970) Central facilities location. Geogr Anal 2(1):30–42
28. Stowers CL, Palekar US (1993) Location models with routing considerations for a single obnoxious facility. Transp Sci 27(4):350–362
29. Tasan AS, Gen M (2012) A genetic algorithm based approach to vehicle routing problem with simultaneous pick-up and deliveries. Comput Ind Eng 62(3):755–761
30. Vincent FY, Lin SY (2015) A simulated annealing heuristic for the open location-routing problem. Comput Oper Res 62:184–196
31. Wasner M, Zäpfel G (2004) An integrated multi-depot hub-location vehicle routing model for network planning of parcel service. Int J Prod Econ 90(3):403–419
32. Watson-Gandy C, Dohrn P (1973) Depot location with van salesmen-a practical approach. Omega 1(3):321–329

33. Wu TH, Low C, Bai JW (2002) Heuristic solutions to multi-depot location-routing problems. Comput Oper Res 29(10):1393–1415
34. Zhang Y, Qi M et al (2015) A metaheuristic approach to the reliable location routing problem under disruptions. Transp Res Part E: Logist Transp Rev 83:90–110
35. Zografros KG, Samara S (1989) Combined location-routing model for hazardous waste transportation and disposal. Transp Res Record (1245):52–59

Part IV
Risk Management

Chapter 53
Submodel Selection and Post-Estimation of the Linear Mixed Models

Syed Ejaz Ahmed and Eugene Afiamoah Opoku

Abstract Linear mixed models (LMM) are popular in a host of business and engineering applications. In this paper, we consider estimation of the regression parameter vector of the LMM when some of the predictors are suspected to be insignificant for prediction purpose. In many practical situations, the investigators may have some information about the important predictors in a given model. Such information, known as uncertain prior information (UPI), could originate from subjective judgement of the investigator based on acquaintance with the experimental or observational data. Further, it is possible to obtain such information based on a variable selection technique, which we refer to as auxiliary information (AE). In any event, whether the information is subjective or data-driven, the resulting submodels are subject to model selection bias. Consequentially, the estimators based on a selected submodel will be biased if the submodel is misspecified. On the other hand, the estimates based on a full model (including all the predictors) may have large variation and/or subject to interpretability issues. To deal with these issues, in the context of two competing models (full model and submodel), we suggest linear shrinkage and shrinkage pretest estimation strategies which combine full model and submodel estimators in an effective way as a trade-off between bias and variance. We examine the performance of the suggested estimators relative to the full model estimator by theoretically using the mean square criterion. We also conduct a Monte Carlo simulation study to assess the performance of listed estimation strategies numerically. Our proposed shrinkage and pretest estimators perform better than the benchmark estimator in a meaningful way. The proposed method is applied to the analysis of a real data set.

Keywords Submodel and full model estimation · Linear mixed models · Pretest and linear shrinkage estimation

---

S.E. Ahmed (✉) · E.A. Opoku
Department of Mathematics and Statistics, Brock University,
Brock, ON L2S3A1, Canada
e-mail: sahmed5@brocku.ca

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_53

53.1 Introduction

Correlated data are commonly encountered in many areas of research including engineering, business and social sciences. A common statistical model is the linear mixed model which contains the fixed effect (regression coefficients) and includes additional random-effects terms. They usually occur as a result of clustering of observations, repeated measuring of the same units and when a time (or space) varying stochastic process is operating on the units [7].

Ahmed et al. [5] analytically discussed the dominance of shrinkage estimators over the usual maximum likelihood estimators for regression coefficients in regression models. These suggested estimators have been investigated and documented in reviewed literature for linear regression models by [1–3].

53.1.1 Model Specification and Estimation

Generally speaking, a mixed model is a model whose function is of both fixed and random effects. There are many books on this topic that are readily available. In this paper, we define the linear mixed model as follows:

$$\mathbf{Y}_i = \mathbf{X}_i\boldsymbol{\beta} + \mathbf{Z}_i\mathbf{a} + \boldsymbol{\varepsilon}_i, \quad i = 1, \ldots, N, \tag{53.1}$$

where $\mathbf{Y}_i$ is an $n_i \times 1$ vector of responses for the ith individual (subject), $\mathbf{X}_i$ and $\mathbf{Z}_i$ are $n_i \times p$ and $n_i \times q$ are known fixed-effects design matrix and random-effect design matrix for the ith subject of rank p and q respectively. The vector $\boldsymbol{\beta}$ is a $p \times 1$ vector of unknown, fixed-effect parameters or regression coefficients. The vector $\mathbf{a}_i$ is a $q \times 1$ vector of unobservable random effects for the ith subject, assumed to come from a multivariate normal distribution with zero mean and a covariance matrix $\mathbf{G}$, where $\mathbf{G}$ is an unknown $q \times q$ covariance matrix. The error term $\boldsymbol{\varepsilon_i}$ denotes $n_i \times 1$ vector of unobservable within-subject error terms assumed to be normally distributed with zero mean and covariance matrix $\sigma^2 I_{n_i}$. Further, they are assumed to be independent of the random effects $\boldsymbol{a}_i$. Hence, the marginal distribution for the response y_i becomes normal with mean $X_i\boldsymbol{\beta}$ and covariance matrix $\text{Var}(\mathbf{Y}_i) = \boldsymbol{\Sigma} = Z_i\mathbf{G}Z_i^T + \sigma^2 I_{n_i}$.

For brevity's sake, we call the model in Eq. (53.1) as the full model. We are primarily interested in the estimation of $\boldsymbol{\beta}$ when either UPI and/or AE are available. The regression parameter vector $\boldsymbol{\beta}$ can be estimated by maximising the marginal likelihood function with respect to $\boldsymbol{\beta}$ under the assumption that random effects terms are to be known. The maximum likelihood estimator (MLE) of $\boldsymbol{\beta}$ is given by

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}^T\boldsymbol{\Sigma}^{-1}\mathbf{X})^{-1}\mathbf{X}^T\boldsymbol{\Sigma}^{-1}\mathbf{Y}.$$

To keep the matter simple, we assume that covariance matrix $\boldsymbol{\Sigma}$ is known and the remaining discussion follows. The MLE $\hat{\boldsymbol{\beta}}$ follows a normal distribution with mean $\boldsymbol{\beta}$ and covariance matrix, $\boldsymbol{\Sigma}_*^{-1} = (\mathbf{X}^T\boldsymbol{\Sigma}^{-1}\mathbf{X})^{-1}$.

As stated earlier, we are interested in estimation of $\boldsymbol{\beta}$ when it can be partitioned as $\boldsymbol{\beta} = (\boldsymbol{\beta}_1, \boldsymbol{\beta}_2)$, where $\boldsymbol{\beta}_1$ and $\boldsymbol{\beta}_2$ have dimensions p_1 and p_2 respectively. Thus, $p_1 + p_2 = p, p_i \geq 0$. Consequently, we partition $\mathbf{X} = (\mathbf{X}_1, \mathbf{X}_2)$ where $\mathbf{X}_1$ is a $n \times p_1$ submatrix containing the active regression variable of interest, $\mathbf{X}_2$ is a collection of $n \times p_2$ submatrix that contains inactive variables for the prediction purpose and can be regarded as nuisance variables. Hence, we are interested in estimating $\boldsymbol{\beta}_1$ when $\boldsymbol{\beta}_2$ may be close to a null vector.

The full model estimator $\hat{\boldsymbol{\beta}}_1$ of $\boldsymbol{\beta}_1$ is given as follows:

$$\hat{\boldsymbol{\beta}}_1 = \left[\mathbf{X}_1\boldsymbol{\Sigma}^{-1/2}\mathbf{M}_{\mathbf{X}_2}\boldsymbol{\Sigma}^{-1/2}\mathbf{X}_1\right]^{-1}\mathbf{X}_1^T\boldsymbol{\Sigma}^{-1/2}\mathbf{M}_{\mathbf{X}_2}\boldsymbol{\Sigma}^{-1/2}\mathbf{Y},$$

where $\mathbf{M}_{\mathbf{X}_2} = \mathbf{I} - \boldsymbol{\Sigma}^{-1/2}\mathbf{X}_2(\mathbf{X}_2\boldsymbol{\Sigma}^{-1}\mathbf{X}_2)^{-1}\mathbf{X}_2^T\boldsymbol{\Sigma}^{-1/2}$.

On the other hand, the submodel or restricted estimator (RE) of $\hat{\boldsymbol{\beta}}_1^{\text{RE}}$ of $\hat{\boldsymbol{\beta}}_1$ is obtained as

$$\hat{\boldsymbol{\beta}}_1^{\text{RE}} = (\mathbf{X}_1^T\boldsymbol{\Sigma}^{-1}\mathbf{X}_1)^{-1}\mathbf{X}_1\boldsymbol{\Sigma}^{-1}\mathbf{Y}.$$

It is well documented in the literature that the submodel estimator performs better than the full model estimator when the assumed information about $\boldsymbol{\beta}_2$ is arguably correct. However, if the assumed information is not precise then $\hat{\boldsymbol{\beta}}_1^{\text{RE}}$ will be subject to bias and its mean squared error may explode. To overcome such difficulty, we suggest some improved estimation strategies in next section.

The paper is organised as follows. The proposed estimation strategies are presented in Sect. 53.2. The asymptotic properties of the proposed estimators are presented in Sect. 53.3. Section 53.4 showcases the findings of a simulation study. A real data example is given in Sect. 53.5. Finally, Sect. 53.6 presents our conclusion.

53.2 Improved Estimation Strategies

We suggest some improved estimation strategies of regression parameter vector, $\boldsymbol{\beta}_1$.

53.2.1 Linear Shrinkage Submodel Estimation

Ahmed [1] suggested an improved estimation technique to balance the potential bias of the submodel estimator by taking the weighted average of the submodel and full model estimate through a fixed value $\pi \in (0, 1)$. Thus we define a shrinkage restricted estimator (SRE) $\hat{\boldsymbol{\beta}}_1^{\text{SRE}}$ of $\boldsymbol{\beta}_1^{\text{SRE}}$ as

$$\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}} = \pi \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}} + (1-\pi)\hat{\boldsymbol{\beta}}_1,$$

where π may be defined as shrinkage intensity.

53.2.2 Pretest Estimation

We suggest the pretest estimation strategy as a combination of the submodel and full model estimators and by incorporating a test-statistic. The pretest estimator of $\boldsymbol{\beta}_1$ is define as a convex combination of $\hat{\boldsymbol{\beta}}_1$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}$, given by

$$\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}} = \hat{\boldsymbol{\beta}}_1 \mathrm{I}(\mathrm{L}_n > d_\alpha) + \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}} \mathrm{I}(\mathrm{L}_n \le d_\alpha),$$

where I(.) is an indicator function with values one or zero, L_n is the test statistics for testing the null hypothesis (H_0): $\boldsymbol{\beta}_2 = \mathbf{0}$.

$$\mathrm{L}_n = \frac{n}{\sigma^2} \hat{\boldsymbol{\beta}}_2^T \mathbf{X}_2^T \mathbf{M}_{\mathbf{X}_1} \mathbf{X}_2 \hat{\boldsymbol{\beta}}_2.$$

Finally, d_α is α -level critical value of the distribution of L_n. Under null hypothesis and for large n, the test statistics L_n follows a chi-square distribution with p_2 degrees of freedom.

53.2.3 Shrinkage Pretest Estimation

Ahmed [5] proposed this improved method of estimation technique by replacing the restricted estimator $\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}$ with the shrinkage restricted estimator $\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}$. Hence, we have

$$\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}} = \hat{\boldsymbol{\beta}}_1 \mathrm{I}(\mathrm{L}_n > d_\alpha) + \hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}} \mathrm{I}(\mathrm{L}_n \le d_\alpha).$$

In the following section we provide some asymptotic properties of the listed estimator.

53.3 Asymptotic Results

We assess the properties of the estimators when n is large. We derive the asymptotic distributional bias (ADB) and asymptotic distributional risk (ADR) of the estimators. In an effort to establish the meaningful asymptotic properties of the estimators, we confine ourselves to a sequence of local alternatives (K_n), given as:

$$K_n : \boldsymbol{\beta_2} = \boldsymbol{\beta_{2(n)}} = \frac{\boldsymbol{\delta}}{\sqrt{n}},$$

where $\boldsymbol{\delta} = (\delta_1, \delta_2, \ldots, \delta_{p_2}) \in \boldsymbol{R}^{p_2}$ is a fixed known vector.

We consider the following weighted quadratic loss function

$$L(\boldsymbol{\beta}_1^{\circ}; \boldsymbol{\beta}_1) = n(\boldsymbol{\beta}_1^{\circ} - \boldsymbol{\beta}_1)^T \mathbf{Q}(\boldsymbol{\beta}_1^{\circ} - \boldsymbol{\beta}_1),$$

where Q is the weighting matrix and $\boldsymbol{\beta}_1^{\circ}$ can be any one of the listed estimators.

Further, we define the asymptotic distribution function of an estimator $\boldsymbol{\beta}_1^{\circ}$ under K_n as

$$\mathrm{G}(y) = \lim_{n\to\infty} P\big[\sqrt{n}(\boldsymbol{\beta}_1^{\circ} - \boldsymbol{\beta}_1) \leq y|K_n\big],$$

where $\mathrm{G}(y)$ is the nondegenerate distribution function of $\boldsymbol{\beta}_1^{\circ}$.

Finally, the asymptotic distributional risk (ADR) is defined as

$$\mathrm{R}\big[(\boldsymbol{\beta}_1^{\circ}; \boldsymbol{\beta}_1); \mathbf{Q}\big] = \int \cdots \int \boldsymbol{y}^T \boldsymbol{Q} \boldsymbol{y} d\mathrm{G}(y) = \mathrm{tr}(\mathbf{Q}\boldsymbol{\Sigma}_{*}{}^{-1}),$$

where $\boldsymbol{\Sigma}_*^{-1} = \int \cdots \int \boldsymbol{y}^T \boldsymbol{y} d\mathrm{G}(\mathbf{y})$ is the covariance matrix for the distribution $\mathrm{G}(\mathbf{y})$.

Similarly, the asymptotic distributional bias (ADB) of an estimator $\boldsymbol{\beta}_1^{\circ}$ as

$$\mathrm{ADB}(\boldsymbol{\beta}_1^{\circ}) = \lim_{n\to\infty} E\big[\sqrt{n}(\boldsymbol{\beta}_1^{\circ} - \boldsymbol{\beta}_1)\big] = \int \cdots \int \boldsymbol{y} d\mathrm{G}(\mathbf{y}).$$

We define the matrix $\mathbf{B}$ as,

$$\mathbf{B} = \begin{bmatrix} \mathbf{B}_{11} & \mathbf{B}_{12} \\ \mathbf{B}_{21} & \mathbf{B}_{22} \end{bmatrix},$$

where $\mathbf{B}_{21}$ and $\mathbf{B}_{22}$ are $p_1 \times p_1$ and $p_2 \times p_2$ matrices respectively, $\mathbf{B}_{22.1} = \mathbf{B}_{22} - \mathbf{B}_{21}\mathbf{B}_{11}^{-1}\mathbf{B}_{12}$; $\mathbf{B}_{11.2} = \mathbf{B}_{11} - \mathbf{B}_{12}\mathbf{B}_{22}^{-1}\mathbf{B}_{21}$, and $\psi_\nu(., \Delta)$ is the distribution function of the non-central chi-square distribution with noncentrality parameter Δ and ν degrees of freedom.

Lemma 53.1 *The test statistics L_n follows a chi-square distribution with p_2 degrees of freedom with noncentrality parameter $\Delta = \boldsymbol{\delta}^T(\mathbf{B}_{22.1}^{-1})\boldsymbol{\delta}$.*

Theorem 53.1 *Under the local alternatives (K_n) and under assumed regularity conditions, the ADBs of the estimators are:*

$$\begin{aligned}
ADB(\hat{\boldsymbol{\beta}}_1) &= \boldsymbol{0}, \\
ADB(\hat{\boldsymbol{\beta}}_1^{RE}) &= -\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}, \\
ADB(\hat{\boldsymbol{\beta}}_1^{SRE}) &= -\pi\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}, \\
ADB(\hat{\boldsymbol{\beta}}_1^{PT}) &= -\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\psi_{p_2+2}(\chi^2_{p_2,\alpha}; \Delta), \\
ADB(\hat{\boldsymbol{\beta}}_1^{SPT}) &= -\pi\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\psi_{p_2+2}(\chi^2_{p_2,\alpha}; \Delta).
\end{aligned}$$

53.3.1 Bias Analysis

Clearly, $\hat{\boldsymbol{\beta}}_1$ is an asymptotically unbiased estimator. Both RE and SRE are biased estimators and are also functions of $\boldsymbol{\delta}$, thus it may explode for larger normalized values $\boldsymbol{\delta}$. It is seen that $\mathrm{ADB}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}) = -\pi \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}$, suggesting that SRE is relatively less biased than RE depending on the the value of $\pi \in (0,1)$. The respective bias function of pretest estimators is bounded in Δ. However, SPT is less biased than $\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$. Further, both pretest estimators are function of α,the size of the test.

In the following theorems we provide the expressions for asymptotic covariance matrices and ADR, respectively.

Theorem 53.2 *Under the local alternatives* (K_n) *and assumed regularity conditions, the asymptotic covariance matrices of the estimators are given as follows:*

$$
\begin{aligned}
Cov(\hat{\boldsymbol{\beta}}_1) &= \mathbf{B}_{11.2}^{-1},\\
Cov(\hat{\boldsymbol{\beta}}_1^{RE}) &= \mathbf{B}_{11}^{-1} + \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{B}_{21}\mathbf{B}_{11}^{-1},\\
Cov(\hat{\boldsymbol{\beta}}_1^{SRE}) &= \pi^2\big[\mathbf{B}_{11}^{-1} + \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{B}_{21}\mathbf{B}_{11}^{-1}\big] + (1-\pi)^2\mathbf{B}_{11.2}^{-1},\\
Cov(\hat{\boldsymbol{\beta}}_1^{PT}) &= \mathbf{B}_{11.2}^{-1}[1-\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)] + \mathbf{B}_{11}^{-1}\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)\\
&\quad + \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{B}_{21}\mathbf{B}_{11}^{-1}[2\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta) - \psi_{p_2+4}(\chi^2_{p_2,\alpha};\Delta)],\\
Cov(\hat{\boldsymbol{\beta}}_1^{SPT}) &= \mathbf{B}_{11.2}^{-1}[1-\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)] + \mathbf{B}_{11}^{-1}\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)\\
&\quad + \pi^2\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{B}_{21}\mathbf{B}_{11}^{-1}[2\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta) - \psi_{p_2+4}(\chi^2_{p_2,\alpha};\Delta)].
\end{aligned}
$$

Theorem 53.3 *Under the local alternatives* (K_n) *and assumed regularity conditions, the ADRs of estimators are*

$$
\begin{aligned}
R\big[\hat{\boldsymbol{\beta}}_1;\mathbf{Q}\big] &= tr(\boldsymbol{Q}\boldsymbol{B}_{11.2}^{-1}),\\
R\big[\hat{\boldsymbol{\beta}}_1^{RE};\mathbf{Q}\big] &= tr(\boldsymbol{Q}\boldsymbol{B}_{11}^{-1}) + \boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{M}\boldsymbol{\delta},\\
R\big[\hat{\boldsymbol{\beta}}_1^{SRE};\mathbf{Q}\big] &= \pi^2\big[tr(\boldsymbol{Q}\boldsymbol{B}_{11}^{-1}) + \boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{M}\boldsymbol{\delta}\big] + (1-\pi)^2 tr(\boldsymbol{Q}\boldsymbol{B}_{11.2}^{-1}),\\
R\big[\hat{\boldsymbol{\beta}}_1^{PT};\mathbf{Q}\big] &= tr(\boldsymbol{Q}\boldsymbol{B}_{11.2}^{-1})[1-\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)] + tr(\boldsymbol{Q}\boldsymbol{B}_{11}^{-1})\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)\\
&\quad + \boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{M}\boldsymbol{\delta}[2\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta) - \psi_{p_2+4}(\chi^2_{p_2,\alpha};\Delta)],\\
R\big[\hat{\boldsymbol{\beta}}_1^{SPT};\mathbf{Q}\big] &= tr(\boldsymbol{Q}\boldsymbol{B}_{11.2}^{-1})[1-\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)] + tr(\boldsymbol{Q}\boldsymbol{B}_{11}^{-1})\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)\\
&\quad + \pi^2\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{M}\boldsymbol{\delta}[2\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta) - \psi_{p_2+4}(\chi^2_{p_2,\alpha};\Delta)],
\end{aligned}
$$

where $\mathbf{M} = \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\mathbf{Q}\mathbf{B}_{21}\mathbf{B}_{11}^{-1}$.

53.3.2 ADR Analysis

When null hypothesis is true, that is, $\boldsymbol{\delta} = \mathbf{0}$, then

$$\mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}) \leq \mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}) \leq \mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}) \leq \mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}) \leq \mathrm{ADR}(\hat{\boldsymbol{\beta}}_1).$$

On the other hand, as $\boldsymbol{\delta}$ moves away from the zero vector, $\mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}})$ and $\mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}})$ monotonically increases in $\lambda = \boldsymbol{\delta}^T \mathbf{M} \boldsymbol{\delta}$ and goes to infinity as λ goes to infinity. However, $\mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}})$ approaches to ∞ at a much slower rate than that of $\mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}})$. The ADR of $\hat{\boldsymbol{\beta}}_1$ remains constant while $\mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}})$ and $\mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}})$ increases, intersecting the line $\mathrm{ADR}(\hat{\boldsymbol{\beta}}_1)$ from below as λ increases. However, near the null hypothesis, for fixed values of α and π

$$\mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}) \geq \mathrm{ADR}(\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}).$$

On the other hand, $(\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}})$ performs better than $(\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}})$ in the remaining parameter space induced by the restriction, that is, $\boldsymbol{\beta}_2 = 0$. In this sense, shrinkage pretest estimator is superior to the pretest estimator. Further, it behaves reasonably for small values of α.

Finally, we would like to note here that unlike $\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}$, both pretest estimators $\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}$ have bounded ADRs and dominate the unrestricted estimator in a meaningful range of the parameter space.

53.4 Simulation Studies

In order to numerically assess the performance of suggested estimators, we conduct a simulation study for selected values of n, α and π. For relative comparison, we consider $\hat{\boldsymbol{\beta}}_1$ as the baseline estimator. For any estimator $\boldsymbol{\beta}_1^*$, we compute the relative mean square error (RMSE) as:

$$\mathrm{RMSE}(\hat{\boldsymbol{\beta}}_1; \hat{\boldsymbol{\beta}}_1^*) = \frac{\mathrm{MSE}(\hat{\boldsymbol{\beta}}_1)}{\mathrm{MSE}(\hat{\boldsymbol{\beta}}_1^*)}.$$

Clearly, if RMSE is greater than one, it indicates the level of superiority of the estimator $\hat{\boldsymbol{\beta}}_1^*$ over $\hat{\boldsymbol{\beta}}_1$. The LMM was fitted for data simulation with designed fixed effects terms, random effects terms and an error structure where we considered a specific number of subjects and observations per subject. The matrices $\mathbf{X}$ and $\mathbf{Z}$ are randomly generated from normal distribution with mean zero, variance 1, and from the uniform distribution respectively. The error term generated from a multivariate normal distribution and within-subject error variance was assumed to be fixed and constant. An unstructured covariance structure (**G**) was assumed for the random effects, where **G** is

$$G = \begin{pmatrix} 1 & 0.5 \\ 0.2 & 2 \end{pmatrix}.$$

To be consistent with the theoretical work, we partition the regression coefficients as $\boldsymbol{\beta} = (\boldsymbol{\beta}_1, \boldsymbol{\beta}_2) = (\boldsymbol{\beta}_1, \mathbf{0})$ and set $\boldsymbol{\beta}_1 = (1, 1, 1, 1, 1, 1)$. Now we define $\triangle = \|\boldsymbol{\beta} - \boldsymbol{\beta}^{(\mathbf{0})}\|$, where $\boldsymbol{\beta}^{(0)} = (\boldsymbol{\beta}_1, \mathbf{0})$ and $\|.\|$ is the Euclidean norm. Clearly, when $\triangle = 0$, we are assuming that the submodel is correctly specified, and opposite conclusion holds for $\triangle > 0$. All computations were conducted using R statistical system [8].

We summarized the simulation results in the tables and figures below for $\alpha = 0.05$ and selected values of (n, π).

We report the result of the simulation experiment in Tables 53.1 and 53.2 and Figs. 53.1 and 53.2 respectively. Clearly for small values of Δ, both SRE and RE outclass all the estimators in the class.

More specifically, at $\Delta = 0$

$$\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}} \succ \hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}} \succ \hat{\boldsymbol{\beta}}_1^{\mathrm{PT}} \succ \hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}} \succ \hat{\boldsymbol{\beta}}_1,$$

where $\succ$ denotes the superiority in terms of MSE.

The simulation results strongly indicate that as the submodels are incorrectly specified the RMSE of $\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}$ decreases and approaches 0 as $\Delta \to \infty$. This behavior of the submodel estimator is consistent with the theoretical findings.

Though departure from the null hypothesis heavily affects $\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}$, it has a relatively lesser impact on $\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}$.

Clearly both $\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$ are a bounded function of Δ. We observe that $\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$ performs better than $\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}$ for smaller values of Δ. However, both $\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$ have

Table 53.1 *RMSE* of estimators with $n = 100$

Δ	$\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}$	$\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}$		$\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$	$\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}$	
		$\pi = 0.4$	$\pi = 0.7$		$\pi = 0.4$	$\pi = 0.7$
0.0	4.52	4.35	4.41	3.91	3.67	3.83
0.3	3.19	3.43	3.50	3.32	3.49	3.50
0.5	2.50	2.39	2.49	2.05	2.11	2.48
1.0	1.10	1.41	1.58	1.20	1.43	1.54
1.6	0.57	0.74	0.79	0.82	1.00	1.00
2.5	0.34	0.41	0.55	1.00	1.00	1.00

Table 53.2 *RMSE* of estimators with $n = 60$

Δ	$\hat{\boldsymbol{\beta}}_1^{\text{RE}}$	$\hat{\boldsymbol{\beta}}_1^{\text{SRE}}$		$\hat{\boldsymbol{\beta}}_1^{\text{PT}}$	$\hat{\boldsymbol{\beta}}_1^{\text{SPT}}$	
		$\pi = 0.4$	$\pi = 0.7$		$\pi = 0.4$	$\pi = 0.7$
0.0	3.91	3.71	4.11	2.92	2.71	2.91
0.3	3.42	3.56	3.62	1.64	1.82	2.12
0.5	2.27	2.51	2.71	1.14	1.48	1.53
1.0	1.08	1.18	1.08	1.03	1.16	1.29
1.6	0.50	0.71	0.69	0.97	1.00	1.00
2.5	0.23	0.47	0.57	1.00	1.00	1.00

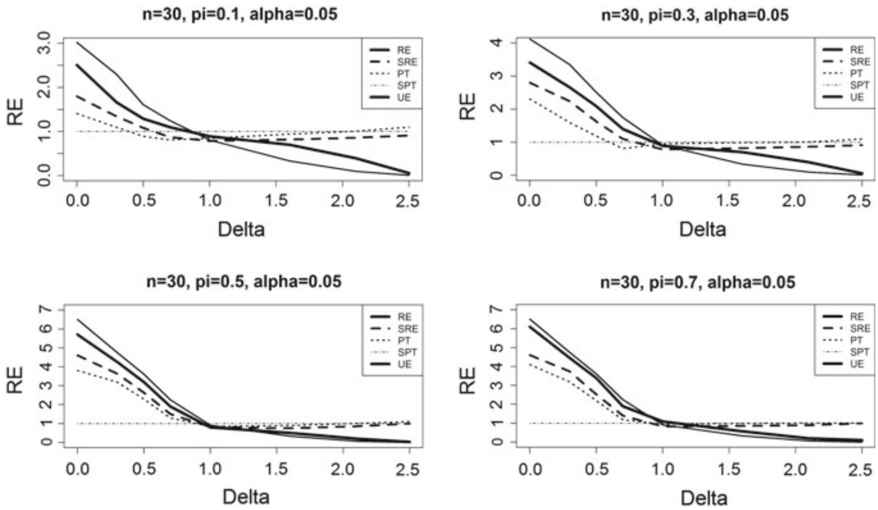


Fig. 53.1 *RMSE* of estimators with selected $\pi = 0.1, 0.3, 0.5, 0.7$

common property in that when $\Delta \to \infty$ their RMSE approaches 1. Further, $\hat{\boldsymbol{\beta}}_1^{\text{SPT}}$ performs better than the benchmark estimator as compared to $\hat{\boldsymbol{\beta}}_1^{\text{ST}}$ in a larger interval of Δ values. This clearly shows the dominance of $\hat{\boldsymbol{\beta}}_1^{\text{SPT}}$ over $\hat{\boldsymbol{\beta}}_1$ and $\hat{\boldsymbol{\beta}}_1^{\text{PT}}$.

We safely conclude that based on simulation study analysis the bias and MSE behavior strongly corroborate with the analytical findings.

53.5 Real Data Application

We present a real data example to illustrate the usefulness of the suggested estimation strategies. We consider fitting a hierarchical linear mixed model on data from a study [9] on the gain in mathematics scores for students in a selection of classrooms in

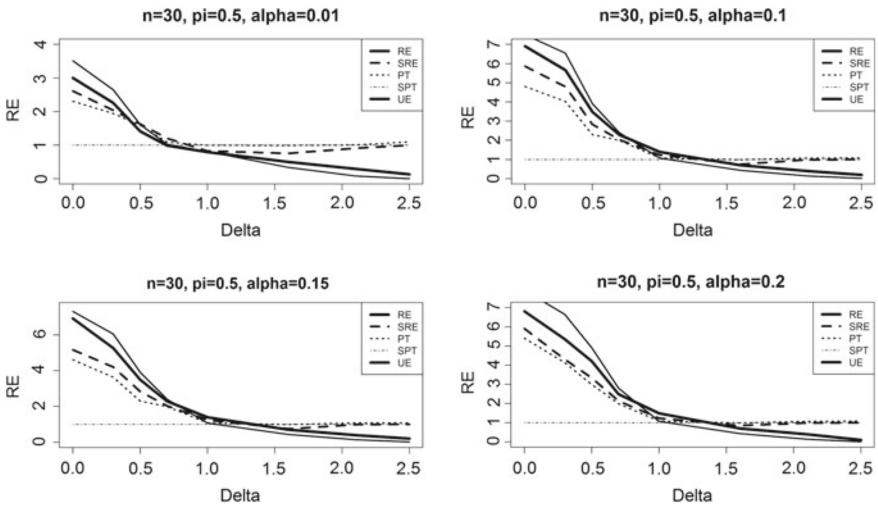


Fig. 53.2 *RMSE* of estimators with selected $\alpha = 0.01, 0.1, 0.15, 0.2$

several schools. The data in question consists of 1190 observations of 12 variables; sex, minority, mathprep, yearstea, housepov, mathkind, mmathknow, student socioeconomic status and the random (nested) effect of class within school. The response variable modeled is mathgain: the difference between a student mathscore at the end of grade one and at the end of kindagarten. Considering the linear mixed effect model of the form:

$$Y_{ij} = \beta_0 + \beta_1 x_{1ij} + \beta_2 x_{2ij} + \cdots + \beta_5 x_{5ij} + b_{i1} z_{1ij} + b_{i2} z_{2ij} + \cdots + b_{in} z_{nij} + \varepsilon_{ij}$$

where Y_{ij} is the value for the response variable for a particular ij case, β_1 through β_5 are the regression coefficients, x_{1ij} through x_{5ij} are the fixed effect variables (predictors) for observation j in group i, b_{i1} through b_{in} are the random effects coefficients which are assumed to be multivariately normally distributed, z_{1ij} through z_{nij} are the random effect variables, and ε_{ij} is the error for case j in group i where each group error is assumed to be multivariate normally distributed.

The preliminary analysis suggests that variables associated $\boldsymbol{\beta}_2$ thus $\{\beta_4, \beta_5\}$ may not be important predictors. Thus we choose a submodel by removing these two variables from the full model. The candidate subspace is $\boldsymbol{\beta}_2 = \{\beta_4, \beta_5\} = (0, 0)$, and in this case, we have $p = 5$, $p_1 = 3$, $p_2 = 2$. The data was bootstrapped to examine the performance on the suggested estimation strategies. We conduct bootstrapping with 2000 replicates in our data example. The performance was evaluated in terms of the RMSE and average prediction errors for the proposed estimators.

The results in Table 53.3 show that as anticipated, the submodel, linear shrinkage, pretest and linear shrinkage pretest estimators are superior to the full model estimation. However, keeping in mind that these results are based on the assumption that

Table 53.3 The RMSE and the average prediction error (APE) for $\pi = 0.5$ and $\alpha = 0.05$

Estimator	$\hat{\boldsymbol{\beta}}_1$	$\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}$	$\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}$	$\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$	$\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}$
RMSE	1.00	2.54	1.93	1.64	1.31
APE	0.624	0.023	0.147	0.321	0.426

the selected submodel is correctly specified. For this reason, the RMSE of the RE is the highest and APE is lowest. This is consistent with our theoretical and simulation results. However, we recommend using the shrinkage pretest estimator since it is well protected if the model is misspecified and performs better than the full model estimator when the submodel is not grossly misspecified.

53.6 Conclusion

Processing data, model building and post-estimation are challenging but rather interesting problems and they commonly occur in a host of fields. Generally, a model builder starts a model with a large number of predictors and then hopes to find a submodel with a small number but most influential predictors. However, one needs to be careful for estimation and prediction based on a submodel at hand due to selection bias. For this reason, we suggested linear shrinkage and pretest estimation strategies for the LMM. Asymptotic results including bias and MSE of the estimators were provided along with the simulation studies.

As we anticipated when the model was correctly specified, the RMSE of the submodel was highest and performed better than the other listed estimators in this paper. However, as restriction moves further away from the assumed subspace, the RMSE converges to zero. The linear shrinkage submodel estimation provided a wider range than the submodel estimator in which it performed better than the full model estimator. The pretest estimators with data-based weights outperform the full model estimator in a meaningful part of the parameter space induced by the candidate subspace. We recommend using the shrinkage pretest estimator since it performs better than the classical estimator in a wider range than the pretest estimator.

Acknowledgments We would like to thank the Prof. Jiuping Xu, Editor-In-Chief and Dr. Zongmin Li for their suggestions and encouragements for this paper. The research is supported by the Natural Sciences and the Engineering Research Council of Canada (NSERC).

Appendix

The distributions of $\hat{\boldsymbol{\beta}}_1$, $\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$ are given by;

$$\begin{aligned}
\boldsymbol{\varphi}_1 &= \sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \boldsymbol{\beta}_1) \to \mathrm{N}_{p_1}\big\{\mathbf{0}, \mathbf{B}_{11.2}^{-1}\big\},\\
\boldsymbol{\varphi}_2 &= \sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}} - \boldsymbol{\beta}_1) \to \mathrm{N}_{p_1}\big\{ - \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}, \mathbf{B}_{11}^{-1}\big\},\\
\boldsymbol{\varphi}_3 &= \sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}} - \boldsymbol{\beta}_1) \to \mathrm{N}_{p_1}\big\{ - \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\psi_{p_2+2}(\chi^2_{p_2,\alpha}; \Delta), \mathbf{B}_{11.2}^{-1}\\
&\quad + (-\mathbf{B}_{11.2}^{-1} + \mathbf{B}_{11}^{-1})\psi_{p_2+4}(\chi^2_{p_2,\alpha}; \Delta)\big\},
\end{aligned}$$

where "$\xrightarrow{d}$" denotes convergence in distribution. $\psi_v(L_n; \lambda)$ is the cumulative distribution function of the non-central chi-squared distribution with non-centrality parameter Δ and v degrees of freedom.

The relationship between submodel and full model estimators of $\boldsymbol{\beta}_1$, is

$$\begin{aligned}
\hat{\boldsymbol{\beta}}_1 &= \big[\mathbf{X}_1\boldsymbol{\Sigma}^{-1/2}\mathbf{M}_{\mathbf{X}_2}\boldsymbol{\Sigma}^{-1/2}\mathbf{X}_1\big]^{-1}\mathbf{X}_1^T\boldsymbol{\Sigma}^{-1/2}\mathbf{M}_{\mathbf{X}_2}\boldsymbol{\Sigma}^{-1/2}y\\
&\quad - \big[\mathbf{X}_1\boldsymbol{\Sigma}^{-1/2}\mathbf{M}_{\mathbf{X}_2}\boldsymbol{\Sigma}^{-1/2}\mathbf{X}_1\big]^{-1}\mathbf{X}_1^T\boldsymbol{\Sigma}^{-1/2}\mathbf{M}_{\mathbf{X}_2}\boldsymbol{\Sigma}^{-1/2}\mathbf{X}_2\hat{\boldsymbol{\beta}}_2\\
&= \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}} - \big[\mathbf{X}_1\boldsymbol{\Sigma}^{-1/2}\mathbf{M}_{\mathbf{X}_2}\boldsymbol{\Sigma}^{-1/2}\mathbf{X}_1\big]^{-1}\mathbf{X}_1^T\boldsymbol{\Sigma}^{-1/2}\mathbf{M}_{\mathbf{X}_2}\boldsymbol{\Sigma}^{-1/2}\mathbf{X}_2\hat{\boldsymbol{\beta}}_2\\
&= \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}} - \mathrm{B}_{11}^{-1}\mathrm{B}_{12}\hat{\boldsymbol{\beta}}_2.
\end{aligned}$$

Proof (Proof of Theorem 53.1) From the definition of ADB,

$$\mathrm{ADB}(\hat{\boldsymbol{\beta}}_1) = E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \boldsymbol{\beta}_1)\big\} = \mathbf{0}.$$

$$\begin{aligned}
\mathrm{ADB}(\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}) &= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}} - \boldsymbol{\beta}_1)\big\} = E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\hat{\boldsymbol{\beta}}_2 - \boldsymbol{\beta}_1)\big\}\\
&= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \boldsymbol{\beta}_1)\big\} - E\big\{\lim_{n\to\infty}\sqrt{n}(\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\hat{\boldsymbol{\beta}}_2)\big\}\\
&= -E\big\{\lim_{n\to\infty}\sqrt{n}(\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\hat{\boldsymbol{\beta}}_2)\big\}\\
&= -\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta},\\
\mathrm{ADB}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}) &= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}} - \boldsymbol{\beta}_1)\big\} = E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \pi\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\hat{\boldsymbol{\beta}}_2 - \boldsymbol{\beta}_1)\big\}\\
&= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \boldsymbol{\beta}_1)\big\} - \pi E\big\{\lim_{n\to\infty}\sqrt{n}(\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\hat{\boldsymbol{\beta}}_2)\big\}\\
&= -\pi E\big\{\lim_{n\to\infty}\sqrt{n}(\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\hat{\boldsymbol{\beta}}_2)\big\}\\
&= -\pi\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta},\\
\mathrm{ADB}(\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}) &= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}} - \boldsymbol{\beta}_1)\big\}\\
&= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - (\hat{\boldsymbol{\beta}}_1 - \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}})\mathrm{I}(L_n \le \chi^2_{p_2,\alpha}) - \boldsymbol{\beta}_1)\big\}
\end{aligned}$$

$$
\begin{aligned}
&= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \boldsymbol{\beta}_1)\big\} - E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}})\mathrm{I}(L_n \le \chi^2_{p_2,\alpha})\big\} \\
&= -E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}})\mathrm{I}(L_n \le \chi^2_{p_2,\alpha})\big\} \\
&= -\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta), \\
\mathrm{ADB}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}) &= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}} - \boldsymbol{\beta}_1)\big\} \\
&= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \pi(\hat{\boldsymbol{\beta}}_1 - \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}})\mathrm{I}(L_n \le \chi^2_{p_2,\alpha}) - \boldsymbol{\beta}_1)\big\} \\
&= E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \boldsymbol{\beta}_1)\big\} - \pi E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{UE} - \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}})\mathrm{I}(L_n \le \chi^2_{p_2,\alpha})\big\} \\
&= -\pi E\big\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \hat{\boldsymbol{\beta}}_1^{\mathrm{RE}})\mathrm{I}(L_n \le \chi^2_{p_2,\alpha})\big\} \\
&= -\pi\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta).
\end{aligned}
$$

Proof (Proof of Theorem 53.2) Suppose the various assumptions hold. Then, under $\{K_n\}$, the asymptotic covariance matrices of the estimators $\hat{\boldsymbol{\beta}}_1$, $\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}$, $\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}$, $\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}$ and $\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}$ are;

Using the identity, for any random vector $\boldsymbol{Y}$, with $\mathrm{E}(\boldsymbol{Y}) = \boldsymbol{\mu}$, $\mathrm{Cov}((\boldsymbol{Y}) = \boldsymbol{\Sigma}$,

$$
\begin{aligned}
E(\boldsymbol{Y}\boldsymbol{Y}^T) &= \boldsymbol{\Sigma} + \boldsymbol{\mu}\boldsymbol{\mu}^{\boldsymbol{T}}, \\
\mathrm{Cov}(\hat{\boldsymbol{\beta}}_1) &= E\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \boldsymbol{\beta}_1)\sqrt{n}(\hat{\boldsymbol{\beta}}_1 - \boldsymbol{\beta}_1)^T\} \\
&= E(\boldsymbol{\varphi}_1\boldsymbol{\varphi}_1^T) = \mathrm{Cov}(\boldsymbol{\varphi}_1\boldsymbol{\varphi}_1^T) + E(\boldsymbol{\varphi}_1)E(\boldsymbol{\varphi}_1^T) \\
&= \mathbf{B}_{11.2}^{-1}, \\
\mathrm{Cov}(\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}}) &= E\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}} - \boldsymbol{\beta}_1)\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}} - \boldsymbol{\beta}_1)^T\} \\
&= E(\boldsymbol{\varphi}_2\boldsymbol{\varphi}_2^T) = \mathrm{Cov}(\boldsymbol{\varphi}_2\boldsymbol{\varphi}_2^T) + E(\boldsymbol{\varphi}_2)E(\boldsymbol{\varphi}_2^T) \\
&= \mathbf{B}_{11}^{-1} + \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{B}_{21}\mathbf{B}_{11}^{-1}, \\
\mathrm{Cov}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}}) &= E\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}} - \boldsymbol{\beta}_1)\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}} - \boldsymbol{\beta}_1)^T\} \\
&= E(\boldsymbol{\varphi}_2\boldsymbol{\varphi}_2^T) = \mathrm{Cov}(\boldsymbol{\varphi}_2\boldsymbol{\varphi}_2^T) + E(\boldsymbol{\varphi}_2)E(\boldsymbol{\varphi}_2^T) \\
&= \pi^2\big[\mathbf{B}_{11}^{-1} + \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\boldsymbol{\delta}^T\mathbf{B}_{21}\mathbf{B}_{11}^{-1}\big] + (1-\pi)^2\mathbf{B}_{11.2}^{-1}, \\
\mathrm{Cov}(\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}}) &= E\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}} - \boldsymbol{\beta}_1)\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{PT} - \boldsymbol{\beta}_1)^T\} \\
&= E(\boldsymbol{\varphi}_3\boldsymbol{\varphi}_3^T) = \mathrm{Cov}(\boldsymbol{\varphi}_3\boldsymbol{\varphi}_3^T) + E(\boldsymbol{\varphi}_3)E(\boldsymbol{\varphi}_3^T) \\
&= \mathbf{B}_{11.2}^{-1}[1 - \psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)] + \mathbf{B}_{11}^{-1}\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta) \\
&\quad + \mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{B}_{21}\mathbf{B}_{11}^{-1}[2\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta) - \psi_{p_2+4}(\chi^2_{p_2,\alpha};\Delta)], \\
\mathrm{Cov}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}}) &= E\{\lim_{n\to\infty}\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}} - \boldsymbol{\beta}_1)\sqrt{n}(\hat{\boldsymbol{\beta}}_1^{\mathrm{SPT}} - \boldsymbol{\beta}_1)^T \\
&= E(\boldsymbol{\varphi}_3\boldsymbol{\varphi}_3^T) = \mathrm{Cov}(\boldsymbol{\varphi}_3\boldsymbol{\varphi}_3^T) + E(\boldsymbol{\varphi}_3)E(\boldsymbol{\varphi}_3^T)
\end{aligned}
$$

$$
\begin{aligned}
=&\mathbf{B}_{11.2}^{-1}[1-\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)]+\mathbf{B}_{11}^{-1}\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)\\
&+\pi^2\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\boldsymbol{\delta}\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{B}_{21}\mathbf{B}_{11}^{-1}[2\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)-\psi_{p_2+4}(\chi^2_{p_2,\alpha};\Delta)],
\end{aligned}
$$

Proof (Proof of Theorem 53.3) By using the definition of risk defined in Sect. 53.3,

$$
\begin{aligned}
&\mathrm{R}\big[\hat{\boldsymbol{\beta}}_1;\mathbf{Q}\big]=\mathrm{tr}(\mathbf{Q}\mathbf{B}_{11.2}^{-1}),\\
&\mathrm{R}\big[\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}};\mathbf{Q}\big]=\pi^2\big[\mathrm{tr}(\mathbf{Q}\mathbf{B}_{11}^{-1})+\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{M}\boldsymbol{\delta}\big]+(1-\pi)^2\mathrm{tr}(\mathbf{Q}\mathbf{B}_{11.2}^{-1}).
\end{aligned}
$$

If $\pi=1$, $\mathrm{R}\big[\hat{\boldsymbol{\beta}}_1^{\mathrm{SRE}};\mathbf{Q}\big]=\mathrm{R}\big[\hat{\boldsymbol{\beta}}_1^{\mathrm{RE}};\mathbf{Q}\big]$.

$$
\begin{aligned}
\mathrm{R}\big[\hat{\boldsymbol{\beta}}_1^{\mathrm{PT}};\mathbf{Q}\big]=&\mathrm{tr}(\mathbf{Q}\mathbf{B}_{11.2}^{-1})[1-\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)]+\mathrm{tr}(\mathbf{Q}\mathbf{B}_{11}^{-1})\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)\\
&+\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{M}\boldsymbol{\delta}[2\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)-\psi_{p_2+4}(\chi^2_{p_2,\alpha};\Delta)],\\
\mathrm{R}\big[\hat{\boldsymbol{\beta}}_1^{SPT};\mathbf{Q}\big]=&\mathrm{tr}(\mathbf{Q}\mathbf{B}_{11.2}^{-1})[1-\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)]+\mathrm{tr}(\mathbf{Q}\mathbf{B}_{11}^{-1})\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)\\
&+\pi^2\boldsymbol{\delta}^{\boldsymbol{T}}\mathbf{M}\boldsymbol{\delta}[2\psi_{p_2+2}(\chi^2_{p_2,\alpha};\Delta)-\psi_{p_2+4}(\chi^2_{p_2,\alpha};\Delta)].
\end{aligned}
$$

where $\mathbf{M}=\mathbf{B}_{11}^{-1}\mathbf{B}_{12}\mathbf{Q}\mathbf{B}_{21}\mathbf{B}_{11}^{-1}$.

References

1. Ahmed SE (2014) Penalty, shrinkage and pretest strategies: variable selection and estimation. Springer, Heidelberg
2. Ahmed SE, Doksum KA et al (2007) Shrinkage, pretest and absolute penalty estimators in partially linear models. Aust N Z J Stat 49(4):435–454
3. Ahmed SE, Hossain S, Doksum KA (2012) Lasso and shrinkage estimation in weibull censored regression models. J Stat Plan Inference 142(6):1273–1284
4. Bancroft TA (1944) On biases in estimation due to the use of preliminary tests of significance. Ann Math Stat 15(2):190–204
5. Chitsaz S, Ahmed SE (2012) An improved estimation in regression parameter matrix in multivariate regression model. Commun Stat-Theory Methods 41(13–14):2305–2320
6. Fuller WA, Battese GE (1974) Estimation of linear models with crossed-error structure. J Econom 2(1):67–78
7. Rencher AC, Schaalje GB (2008) Linear models in statistics. Wiley, New York
8. Team RC (2014) R: A language and environment for statistical computing. Foundation for Statistical Computing, Vienna, Austria 2013
9. West BT, Welch KB, Galecki AT (2014) Linear mixed models: a practical guide using statistical software. CRC Press, Boca Raton

Chapter 54
Bi-Level Water Allocation Model Based on Shortage Control

Yan Tu, Ning Ma, Jun Gang, Xiaoyang Zhou and Benjamin Lev

Abstract This paper aims to develop a bi-level model with multiple followers to make decision on water resources allocation, water shortage control objective is considered by the leader, cost saving objectives are considered by the followers. In the model, random fuzzy variables are considered, these variables are transformed to determined variables using expected value operator to make the model calculable. Finally, a case is applied to verify the efficiency of the proposed model and algorithm.

Keywords Bi-level programming · Water allocation · Water shortage control · Random fuzzy · Particle swarm optimization

54.1 Introduction

With the increase of population, development of economic and destruction of ecological environment, the gap of water resources between supply and demand is gradually increasing [3]. Due to the uneven distribution of water resources, the water resources crisis is more severe, and areas with scarce water resources are more and more. Water

Y. Tu
School of Management, Wuhan University of Technology,
Wuhan 430070, People's Republic of China

N. Ma
Business School, Sichuan University, Chengdu 610064, People's Republic of China

J. Gang
Sichuan Institute of Building Research, Chengdu 610081, People's Republic of China

X. Zhou (✉)
International Business School, Shaanxi Normal University,
Xi'an 710062, People's Republic of China
e-mail: x.y.zhou@foxmail.com

B. Lev
Decision Sciences Department, LeBow College of Business,
Drexel University, Philadelphia, PA 19104, USA

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_54

resources influence every aspect of economic and ecological environment, there is a close connection between them, they can promote each other but may may restrict each other. Unreasonable water resources allocation decision will affect the stability and development of the society [2, 5]. The water shortage region of China accounts for a large part of the land area, because of the huge population base, the uneven north and South Distribution of water resources, rapid economic development, the lack of water resources in China is more serious than many other countries in the world. In the specific region and in the season of water resources shortage, if the water resources allocation is uneven, the lack of water resources will be more, the society will more unstable, that is, the social benefits are lower, which does not meet the principle of water resource allocation [6]. Therefore, the size of the water shortage has become an important indicator to measure the rationality of the water resources allocation.

It is not reasonable to just consider the decision making of regional authority in water resources allocation for it will cause water waste in high (over) allocated areas, and water shortage in low (under) allocated areas [7]. The decision makings of regional authority and the managers of sub districts are considered together, and regional authority is the leading decision maker (leader) and the managers of sub districts are the following decision makers (followers), therefore, this problem can be abstracted as a bi-level model. The leader and the followers have their own objectives. Moreover, it is well known that there are many uncertain factors in water resources system [1]. In this paper, the random fuzzy variables are considered to model the uncertain factors, so the bi-level model for water resources allocation is considered under a random fuzzy environment. For getting the solution of the problem, an improved particle swarm optimization (IPSO) is used because of its advantages to solve many hard optimization problems compared with other optimization methods [4].

The reminder of this paper is organized as follows. In the next section, the description of the water allocation problem is given. In Sect. 54.3, the modelling process of the proposed problem is presented. In Sect. 54.4, a case study is conducted. Finally, the conclusion is provided in Sect. 54.5.

54.2 Problem Description

In a regional area, according to the topography, water conservancy conditions, administrative divisions of the region, the region generally can be divided into a number of sub districts.

In this problem, the water resources regional authority, which is the leading decision maker (i.e., leader), make decisions on public water rights allocation yo sub districts, it mainly considers the overall interests (i.e., the social benefits of water allocation). There are many measure methods on social benefits of water allocation, in which water shortage can reflect social benefits of water allocation directly. The managers of sub districts receive the allocated water, with consideration of ecological maintenance of own fields and benefits of water using in different water sectors, they reallocate the water to each water sector besides ecological water to achieve maximal economic benefit.

From the description above, the regional authority and the sub districts are independent, the water allocation problem can be abstracted as a bi-level programming with multiple followers in the lower level, in which the regional authority is the leader, who aims to achieve the goal of minimizing the amount of water shortage, it distributes public water rights among different sub districts, the managers of sub districts are the followers, after they get the water tights, with consideration of ecological water use, they reallocate the rest of water resources among water sectors to obtain maximum economic benefits (Fig. 54.1).

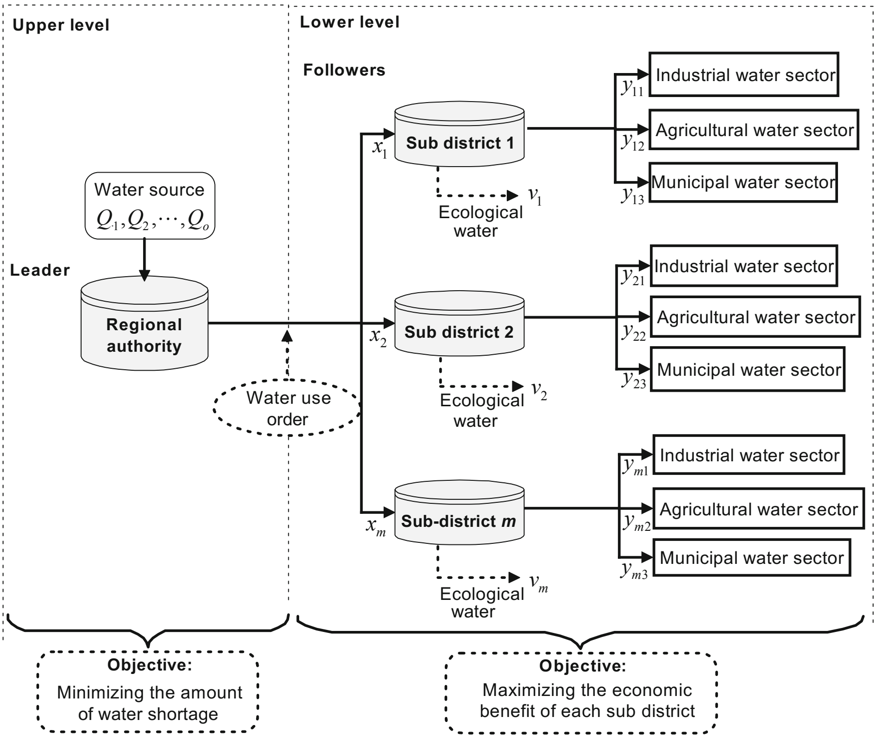


Fig. 54.1 Bi-level structure of the water allocation problem

54.3 Modelling

Before establishing the mathematical model of regional water resources allocation problem, the basic assumptions, the notations are introduced.

54.3.1 Assumptions

The model is built based on the following assumptions:

(1) The minimum water flow in each sub district must meet minimum ecological water demand, the maximum and minimum water withdrawals and sewage discharge coefficient of each water sector are known.
(2) Each sub district has its own sewage discharge total limit requirement.
(3) The water demand of each sub district is considered as random fuzzy variables, the random parameters follows normal distributions, and the parameters are determined by historical data and professional experience.

54.3.2 Notations

The following notations are used to build the model.
Indices

i: Sub district, $i = 1, 2, \ldots, m$;
j: Water sector, $j = 1, 2, \ldots, n$;
k: Water source, $k = 1, 2, \ldots, o$.

Certain parameters

Q_k: Water supply of water source k;
q_{ik}: Water supply to water sector j from source k;
v_i: Ecological water of sub district i;
λ_{ij}: Concentration of important pollution factors in the discharge of sewage of water sector j in sub district i;
p_{ij}: Sewage discharge coefficient of water sector j in sub district i;
ew_i: Sewage carrying capacity of sub district i;
ρ_i: Water supply order coefficient of sub district i;
e_{ij}: Economic benefits of water use of water sector j in sub district i;
$z_i^{\min}$: Minimum water supply capacity of public water source;
$z_i^{\max}$: Maximum water supply capacity of public water source.

Random fuzzy variables

$\tilde{\bar{r}}_{ij}$: Water demand of water sector j in sub district i;

$\tilde{\bar{g}}_i$: Basic ecological water demand of sub district i.

Decision variables

x_i: Water rights allocated to sub district i, which is the decision variable of upper level;

y_{ij}: Water use of sector j in sub district i, which is the decision variable of lower level.

54.3.3 Bi-level Model Construction

In the proposed problem, regional authority, as the leader, aims to minimize the water shortage in the whole region.

(1) Objective of the upper level

Because the amount of water shortage will influence the stability of the society. Minimum water shortage corresponds to the minimum loss for the water shortage. Namely, minimum regional total water shortage reflects highest social benefit. The objective of the upper level is to minimize the regional water shortage, based on the notations above and let F denote the objective function, the following expression can be obtained

$$\min_{x_i} F = \sum_{i=1}^{m} \left[\sum_{j=1}^{n} \tilde{\bar{r}}_{ij} - (x_i - v_i) \right] \rho_i. \tag{54.1}$$

As $\tilde{\bar{r}}_{ij}$ is a random fuzzy variable, the decision maker cannot obtain determined demand. According to Xu and Yao [8], the expected value of the objective can be obtained as follows.

$$\min_{x_i} F = E\left[\sum_{i=1}^{m} \left[\sum_{j=1}^{n} \tilde{\bar{r}}_{ij} - (x_i - v_i) \right] \rho_i \right] = \sum_{i=1}^{m} \left[\sum_{j=1}^{n} E\left[\tilde{\bar{r}}_{ij}\right] - (x_i - v_i) \right] \rho_i. \tag{54.2}$$

(2) Constraints of the upper level

There are three kinds of constraints in the upper level.

- Water supply constraint

Water supplied to all sub districts cannot be over than the total available water, water supplied to all water sectors from water source k cannot be over than the available water in source k, based on the above notations, we can obtain the following constraints.

$$\sum_{i=1}^{m} x_i \leq \sum_{k=1}^{o} Q_k, \tag{54.3}$$

$$\sum_{j=1}^{n} q_{jk} \leq Q_k, \quad \forall k. \tag{54.4}$$

• Water conveyance capacity constraint

Water allocated to sub district i should be between the minimal and maximal water conveyance capacities, therefore, we can get the following constraints.

$$z_i^{\min} \le x_i \le z_i^{\max}, \quad \forall i. \tag{54.5}$$

• Nonnegativity condition

Water allocated to each sub district should be nonnegative, thus the following constraints can be obtained.

$$x_i \ge 0, \quad \forall i. \tag{54.6}$$

The followers are the managers of sub districts, they aims to make decisions on allocating water to sectors to obtain the maximal economic benefits.

(3) Objectives of the lower level

Let f_i denote the objective function of sub district i, as the objective of sub district i is to maximize the economic benefit, so we can obtain the following objectives.

$$\max_{y_{ij}} \ f_i = \sum_{j=1}^{n} e_{ij} y_{ij}, \quad \forall i. \tag{54.7}$$

(4) Constraints of the lower level

There are four kinds of constraints in the lower level.

• Water withdrawal constraint

Water withdrawal in sub district i cannot be over than the allocated water, and water withdrawal of sector j cannot be over than allocated water to it from all the water sources. Therefore, we can get the following constraints.

$$\sum_{j=1}^{n} y_{ij} + v_i \le x_i, \quad \forall i, \tag{54.8}$$

$$\sum_{i=1}^{m} y_{ij} \le \sum_{k=1}^{o} q_{jk}, \quad \forall j. \tag{54.9}$$

• Ecological water demand constraint

In order to maintain the sustainable development, ecological water demand should be met.

$$v_i \ge \tilde{\tilde{g}}_i, \quad \forall i. \tag{54.10}$$

Using the expected value operator according to Xu and Yao [8], the above constraints can be transformed as follows.

$$v_i \ge E\left[\tilde{\tilde{g}}_i\right], \quad \forall i. \tag{54.11}$$

- Sewage discharge constraint

Sewage discharge of sub district i cannot exceed the capacity, thus the following constraints can be obtained.

$$\sum_{j=1}^{n} 0.01\lambda_{ij} p_{ij} y_{ij} \leq ew_i, \quad \forall i. \tag{54.12}$$

- Nonnegativity condition

Water withdrawal should be nonnegative, thus the following constraints can be obtained.

$$y_{ij} \geq 0, \quad \forall i, j. \tag{54.13}$$

(5) Global model for water allocation

By integrating Eqs. (54.2)–(54.9), (54.11)–(54.13), the following global model for water allocation based on water shortage control is built as follows.

$$\begin{aligned}
&\min_{x_i} \; F = \sum_{i=1}^{m} \left[\sum_{j=1}^{n} E\left[\tilde{\bar{r}}_{ij}\right] - (x_i - v_i) \right] \rho_i \\
&\text{s.t.} \begin{cases}
\sum_{i=1}^{m} x_i \leq \sum_{k=1}^{o} Q_k \\
\sum_{j=1}^{n} q_{jk} \leq Q_k, \quad \forall k \\
z_i^{\min} \leq x_i \leq z_i^{\max}, \quad \forall i \\
x_i \geq 0, \quad \forall i \\
\max_{y_{ij}} \; f_i = \sum_{j=1}^{n} e_{ij} y_{ij}, \quad \forall i \\
\text{s.t.} \begin{cases}
\sum_{j=1}^{n} y_{ij} + v_i \leq x_i, \quad \forall i \\
\sum_{i=1}^{m} y_{ij} \leq \sum_{k=1}^{o} q_{jk}, \quad \forall j \\
v_i \geq E\left[\tilde{\bar{g}}_i\right], \quad \forall i \\
\sum_{j=1}^{n} 0.01\lambda_{ij} p_{ij} y_{ij} \leq ew_i, \quad \forall i \\
y_{ij} \geq 0, \quad \forall i, j.
\end{cases}
\end{cases}
\end{aligned} \tag{54.14}$$

54.4 Case Study

In this section, the water allocation in X city is taken as an application example to illustrate the practicality and effectiveness of the proposed bi-level model.

54.4.1 Case Description

According to the administrative division, X city can be divided into two districts: sub district I and sub district II. The water sources of X city are one diversion project (mainly for agricultural water use), shallow groundwater and deep groundwater, water supply situation of X city can be seen in Table 54.1, the water demand of all water sectors in sub districts can be seen in Table 54.2, the known data of many other parameters on water sectors are shown in Table 54.3, and the known data of many other parameters on sub districts are shown in Table 54.4.

Table 54.1 Water supply in X city (10^4 m^3)

	Water source					
	Diversion project	Subtotal	Shallow groundwater	Deep groundwater	Subtotal	Total
Whole city	17885	17885	7352	13654	21006	38891

Table 54.2 Water demand all water sectors in sub districts (10^4 m^3)

Water sector	Sub district	
	Sub district I	Sub district II
Municipal water use ($j = 1$)	$\tilde{\bar{r}}_{11} \sim N(\mu^r_{11}, 25)$ $\mu^r_{11} = (3460, 3476, 3501)$	$\tilde{\bar{r}}_{21} \sim N(\mu^r_{21}, 16)$ $\mu^r_{21} = (2800, 2837, 2868)$
Industrial water use($j = 2$)	$\tilde{\bar{r}}_{12} \sim N(\mu^r_{12}, 49)$ $\mu^r_{12} = (6681, 6735, 6798)$	$\tilde{\bar{r}}_{22} \sim N(\mu^r_{22}, 25)$ $\mu^r_{22} = (3139, 3180, 3227)$
Agricultural water use ($j = 3$)	$\tilde{\bar{r}}_{13} \sim N(\mu^r_{13}, 36)$ $\mu^r_{13} = (5802, 5853, 5897)$	$\tilde{\bar{r}}_{23} \sim N(\mu^r_{23}, 25)$ $\mu^r_{21} = (4769, 4818, 4875)$
Ecological water	$\tilde{\bar{g}}_1 \sim N(\mu^g_1, 1)$ $\mu^g_1 = (21, 23, 25)$	$\tilde{\bar{g}}_2 \sim N(\mu^g_2, 0.81)$ $\mu^g_2 = (16, 17, 18)$

Table 54.3 Other parameters on water sectors

Sub district	Parameter	Water sector		
		Municipal water use ($j = 1$)	Industrial water use ($j = 2$)	Agricultural water use ($j = 3$)
Sub district I ($i = 1$)	Unit economic benefit	500	250	5.5
	Sewage discharge coefficient	0.70	0.64	0.25
	Pollutant concentration (mg/l)	300	275	120
Sub district II ($i = 2$)	Unit economic benefit	475	240	5.0
	Sewage discharge coefficient	0.72	0.62	0.30
	Pollutant concentration (mg/l)	325	250	100

Table 54.4 Other parameters of sub districts

Parameter	Sub district	
	Sub district I ($i = 1$)	Sub district II ($i = 2$)
Sewage carrying capacity (m^3)	20810	12860
Water supply order coefficient	0.4	0.6
Minimum supply capacity ($10^7\ m^3$)	5.5	5.0
Maximum supply capacity ($10^7\ m^3$)	12.5	12.0

54.4.2 Results Analysis

Based on the above data and the analysis of the bi-level model, the allocation results can be obtained in Table 54.5.

It can be known from Table 54.5 that the objective of the leader is $F = 1632.0$, the objectives of sub district I and sub district II are $f_1 = 3113707.9$, $f_2 = 1992790.5$.

Table 54.5 Other parameters of sub districts

Sub district	Allocated water	Ecological water	Total water shortage	Water sector			Economic benefit
				Municipal water user (−Shortage)	Industrial water user (−Shortage)	Agricultural water use (−Shortage)	
Sub district I	10291.8	23.0	2206.1	3476.3 (0)	5394.7 (−1342.6)	4887.8 (−863.5)	3113707.9
Sub district II	8139.7	17.0	1249.3	2835.2 (0)	2607.7 (−573.8)	4044.5 (−675.5)	1992790.5
Total	18451.5	40.0	3455.4	6311.5	8002.4	8932.3	5106498.4

54.5 Conclusion

This paper considers a regional water allocation problem. In this problem, not only the decision of the regional authority but also the decisions of the sub districts are considered, the most important optimization objective is to maximize the social benefit, which is measured by the water shortage, this objective is optimized by the regional authority, the sub districts have their own objectives to maximize the economic benefit. Therefore, the problem is abstracted as a bi-level model, the regional authority is the leader and the sub districts are the followers. Finally, a case study is used to illustrate the practicality of the proposed model.

Acknowledgments Support was provided by the National Natural Science Foundation of China (Grant No. 71401093) and the Fundamental Research Funds for the Central Universities (Grant No. 14SZYB08).

References

1. Bender MJ, Simonovic SP (2000) A fuzzy compromise approach to water resource systems planning under uncertainty. Fuzzy Sets Syst 115(1):35–44
2. Cai X (2008) Water stress, water transfer and social equity in Northern Chinałimplications for policy reforms. J Env Manag 87(1):14–25
3. Dijk AI, Beck HE et al (2013) The millennium drought in Southeast Australia (2001–2009): natural and human causes and implications for water resources, ecosystems, economy, and society. Water Resour Res 49(2):1040–1057
4. Gao Y, Zhang G et al (2011) Particle swarm optimization for bi-level pricing problems in supply chains. J Glob Optim 51(2):245–254
5. Han Y, Xu Sg, Xu Xz (2008) Modeling multisource multiuser water resources allocation. Water Resour Manag 22(7):911–923
6. Osorio J, Osorio M et al (1998) Water deficits are more important in delaying growth than in changing patterns of carbon allocation in eucalyptus globulus. Tree Physiol 18(6):363–373
7. Tu Y, Zhou X et al (2015) Administrative and market-based allocation mechanism for regional water resources planning. Resour, Conserv Recycl 95:156–173
8. Xu J, Yao L (2011) Random-like multiple objective decision making, vol 647. Springer Science & Business Media, Berlin

Chapter 55
A Fuzzy Multi-criteria Decision Making Method for the Financial Statement Quality Evaluation

Nguyen Thi Hoai Thuong, Zongmin Li and Phi Thi Diem Hong

Abstract This paper provides a fuzzy multi-criteria decision making (FMCDM) method for evaluating financial statement quality (FSQ). Current research rarely applied the multi-criteria evaluation method to evaluate FSQ, and the fuzzyness was ignored. Accordingly, this paper develops a FMCDM method for FSQ. Firstly, an evaluation index system is established based on the key qualitative characteristics of financial reporting information defined by the International Financial Reporting Standards (IFRS). The evaluation index system contains four criteria, which are relevance, reliability, comparability, and understandability. After that, this paper develops an intuitionistic fuzzy weighted averaging operator for weighting criteria, and a fuzzy distance-based method for weighting evaluators' judgements. Thereafter, this paper uses a revised TOPSIS method to aggregate all the qualitative ratings. A practical case study is used to test the feasibility of the methodology. Finally, we discuss the effectiveness of the proposed method. Compared with previous FSQ evaluation approaches, the proposed FMCDM method takes more aspects into consideration, and has significant advantages.

Keywords Fuzzy multi-criteria decision making · Financial statement quality · Companies' annual financial statement · IFRS · TOPSIS

N.T.H. Thuong · Z. Li (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: lizongmin@scu.edu.cn

N.T.H. Thuong · P.T.D. Hong
Financial Accounting Department, Faculty of Accounting and Business Management, Vietnam National University of Agriculture, Hanoi, Vietnam

P.T.D. Hong
Department of Commerce, Faculty of Economic, Komazawa University, Tokyo, Japan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_55

55.1 Introduction

Financial statement quality (FSQ) evaluation is both practically and theoretically important. As is well known, financial information are useful not only for the directors but also any investors, shareholders, creditors, financial analysts, competitors, suppliers, customers, and owners [3, 5, 8]. The quality of financial statements is critical to discover the financial position and financial results of a business [17]. Also it is helpful for researchers in making and improving high quality of financial reports.

Many papers have mentioned and evaluated the quality of financial statements based on different methodologies, such as hypothetical statistical tests, data analysis, sample selection, information content testing, bank questionnaire [1, 7, 10, 20]. On the other hand, a lot of the current researches have been applied the method of the fuzzy multi-criteria decision making (FMCDM) method to discover and solve many sciences problems. The theory and method of FMCDM is well developed. Current research rarely applied the multi-criteria evaluation method to evaluate FSQ, and the fuzzyness was ignored. To be a beneficial attempt for the application of FMCDM and FSQ evaluation, this paper provides a FMCDM method for evaluating FSQ.

The concepts of FMCDM have been widely used to solve many problems in scientific researches. Employing FMCDM methods has been proven to be a very effective technique to increase the level of overall satisfaction for the final decision across the group and particularly in evaluation decision making [11]. Multi-criteria evaluation is a fundamental step of the rational decision making process. The purpose of evaluation is to gain reliable information on strengths, weakness and overall utility of each option [6]. Li et al. [9] identified and introduced methods of FMCDM for evaluating individual research output. The authors [9] developed a fuzzy multi-criteria group evaluation method to achieve maximum group consensus including the fuzzy distance-based and aggregation methods. The method is very suitable for FSQ evaluation. This paper therefore considers re-introducing and applying those same methods in a new problem of FSQ evaluation.

According to the current International Financial Reporting Standards (IFRS), there are some qualitative characteristics of financial information consist of fundamental qualities including relevance and reliability, and enhancing qualities including comparability, verifiability, timeliness and understandability. As Alexander and Nobes [3] mentioned that having four main qualitative characteristics that influence the usefulness of accounting information, which include relevance, reliability, comparability, and understandability. In this study, we identify these four main qualitative characteristics as key evaluation criteria of financial reports. In order to assess the key qualities that influence the usefulness of accounting information, a fuzzy distance-based method is developed for evaluator weights determination. We minimize the sum of Euclidean distances between all pairs of ratings and thus make them achieve maximum consensus. In addition, an intuitionistic fuzzy weighted averaging operator is applied to determine criteria weights, so that importance of criteria can be determined experts' intuitionistic description [9]. Considering that all the ratings are fuzzy numbers, this paper extends the Technique for Order Preference by

Similarity to Ideal Solution (TOPSIS) method to the fuzzy environment to aggregate all evaluation results.

The remaining of the paper is organized as follow: in Sect. 55.2, the key problem of FSQ evaluation is described; Sect. 55.3 introduces the methodology for FSQ evaluation, which includes the evaluation index system, weighting methods, aggregation method and general framework; Sect. 55.4 presents a case from a Vietnam economic group with many joint-stock companies and subsidiary companies to show the application of the proposed methodology; Sect. 55.5 concludes with summary.

55.2 Key Problem Statement

As pointed out by Mardani [12], MCDM is considered as a complex decision-making tool involving both quantitative and qualitative factors. The recent some applications of fuzzy MCDM are farther than enough to reflect the huge contributions of FMCDM in real life applications [2, 6, 12]. Some of these applications involved production, manufacturing, location-allocation problems, environmental management, business, marketing, agriculture economics, machine control, engineering applications and regression modeling as pointed out by El-Wahed [6]. In this paper, the research develops a fuzzy multi-criteria evaluation method to assess the quality of companies' financial statements. The aim of multi-criteria evaluation of the FSQ is using the methodology of FMCDM to evaluate four key qualities of the financial reports by the IFRS's concept.

According to the current IFRS, there are four qualitative characteristics that influence the usefulness of accounting information: relevance, reliability, comparability, understandability. This paper reviews, considers, evaluates, and comments on existing researches on the importance of the information quality in the financial statements for various users. As pointed out by Palea [13], financial information influences users' behavior relating to making decision in business. However; it is not all financial report's readers know that how to distinguish the information in financial statements is truly relevant, reliable, comparable, and understandable or not. Also, though both relevance and reliability are very important, the problem that we often face in accounting is that information that is highly relevant may not be very reliable. Similarly, that which is reliable may not be very relevant [3].

In order to evaluate and improve the quality of the information in financial statements, this study focuses on representation two methods of FMCDM which use to assess the quality of companies' annual financial statements, namely a weighting method and an aggregation method. That methods of FMCDM are not very new methodology but their usefulness remain unchanged; however it looks like an updated method supports improving the quality of Financial Accounting Management System. Especially the more detail about applied methods in the FSQ evaluation will be present in the next section.

55.3 Methodology

This section formulates a fuzzy multi-criteria evaluation process for FSQ evaluation, including the identification of evaluation criteria, general framework, determination of weights, and aggregation method.

55.3.1 Establishment of the Evaluation Index System

According to the current IFRS, as shown in Fig. 55.1, there are four main qualitative characteristics that influence the usefulness of accounting information, therefore we use that qualities as the key evaluation criteria of FSQ:

1. Relevance (denoted by *C1*);
2. Reliability (denoted by *C2*);
3. Comparability (denoted by *C3*);
4. Understandability (denoted by *C4*).

(1) Relevance (*C1*)

Accounting information must have the ability to influence decision. Unless this characteristic is present, there is really no point in producing the information. The information may be relevance to the prediction of future events (for example, in prediction how much profit is likely to be earned next year) or relevant in helping to confirm past events (for example, in establishing how much profit was earned last year). The role of accounting in confirming the past events is important because users often wish to check the accuracy of earlier predictions that they have made. The accuracy (or inaccuracy) of earlier predictions may help users to judge the accuracy of current prediction. To influence a decision, the information must be available when the decision is being made. Thus, relevant information must be timely [3, 14, 17].

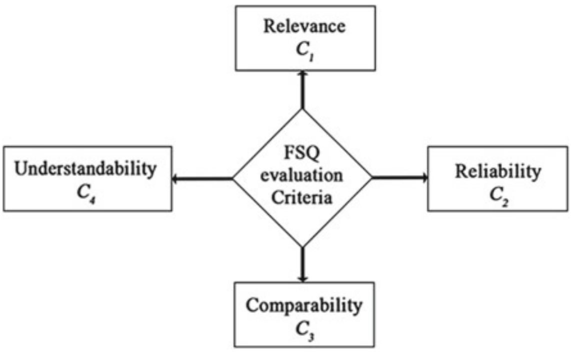


Fig. 55.1 Four main qualitative characteristics of financial statements

(2) Reliability (*C2*)

Accounting should be free from significant error or bias. It should be capable of being relied upon by managers to present what it is supposed to represent. Though both relevance and reliability are very important, the problem that we often face in accounting is that information that is highly relevant may not be very reliable. Similarly, that which is reliable may not be very relevant. When seeking to strike the right balance between relevance and reliability, the needs of users should be the overriding consideration [3, 14, 19].

(3) Comparability (*C3*)

This quality will enable users to identify changes in the business over time (for example, the trend in sales revenue over the past five years). It will also help them to evaluate the performance of the business in relation to similar businesses. Comparability is achieved by treating items that are basically the same in the same manner for accounting purposes. Comparability may also be enhanced by making clear the policies that have been adopted in measuring and presenting the information [3, 17].

(4) Understandability (*C4*)

Accounting reports should be expressed as clearly as possible and should be understood by those at whom the information is aimed [3, 17].

55.3.2 *General Framework*

The general framework for FMCDM of FSQ evaluation is shown in Fig. 55.2.

As shown in Fig. 55.2, there are p evaluators, i,e., $E_i(i = 1, 2, \ldots, p)$, m criteria, i.e., $C_j(j = 1, 2, \ldots, m)$, and n companies to be evaluated, i.e., $A_k(k = 1, 2, \ldots, n)$. This paper considers two hierarchy, i.e., the hierarchy of evaluators (Annual financial statements) and the hierarchy of criteria which are necessary for FMCDM as pointed out by Ma et al. [11]. A fuzzy distance-based method and an intuitionistic fuzzy weighted averaging operator are applied respectively for evaluator and criteria weight

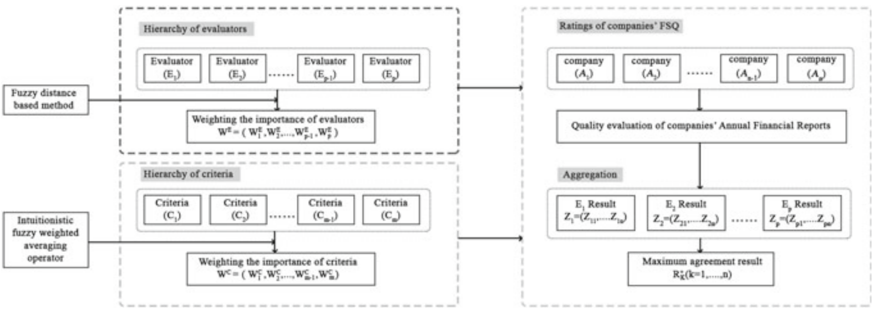


Fig. 55.2 The general framework for the FMCDM methodology of FSQ evaluation

determination. After each evaluator giving the ratings of each company's FSQ for each criteria, a revised TOPSIS aggregation method is used to get the final evaluation result.

55.3.3 Weighting Method

In the process of FSQ multi-criteria evaluation, a group of evaluators (i.e., members of joint-stock companies and subsidiary companies) are involved in a complex decision process and each of them plays a different role. Usually, the weights of evaluators differ because of their position, prestige, financial accounting management experience, accountants' quantity and quality, etc. However, sometime it is difficult to judge evaluators' important in FSQ evaluation. A practical situation that occurs frequently for example, is when one evaluator is high in accountants' quantity and quality but is relatively low in accounting management experience, or one evaluator is high in accounting management experience but low in accountants' quality, and another evaluator is high in accountants' quantity but low in accountants' quality. Therefore, this paper applies a fuzzy distance-based method for determining evaluators' weight ($W^E = \{w_i^E, i = 1, \ldots, p\}$) to achieve maximum agreement between all evaluators. Our general idea is to minimize the sum of the Euclidean distance from one evaluator's result to another.

Evaluators first make their own judgments of companies' annual financial statement quality based on qualitative evaluation criteria C_1–C_4. Ratings under qualitative evaluation criteria are considered as linguistic variables. As pointed cut by Zadeh [23], a linguistic variable is a variable whose values are words or sentences in a natural or artificial language. It is very useful in dealing with situations which are ill-defined to be described properly in conventional qualitative expressions [24]. The quality of the information in the companies' annual financial statements under each qualitative evaluation criteria can be expressed on a 7-point rating scale: "very good", "good", "medium good", "fair", "medium poor", "poor", and "very poor". Such linguistic variables are converted into triangular intuitionistic fuzzy numbers (IFNs) [4, 24] as shown in Table 55.1. IFNs are commonly used for solving decision-making

Table 55.1 Linguistic variables and triangular IFNs for ratings under the FSQ evaluation criteria

Linguistic variables	Triangular IFNs
Very good (VG)	(0.9, 1.0, 1.0)
Good (G)	(0.7, 0.9, 1.0)
Medium good (MG)	(0.5, 0.7, 0.9)
Fair (F)	(0.3, 0.5, 0.7)
Medium poor (MP)	(0.1, 0.3, 0.5)
Poor (P)	(0.0, 0.1, 0.3)
Very poor (VP)	(0.0, 0.0, 0.1)

problems, where the variable information is imprecise. There are different shapes or forms of IFNs, among those, trapezoidal IFNs and triangular IFNs are the most commonly used. For example, Shaw and Roy [15] used trapezoidal IFNs for analyzing fuzzy system reliability, while Vahdani et al. [18] applied triangular IFNs to fuzzy group decision-making problems with an application to the contractor selection. This paper chooses to use the triangular IFNs because of their conceptual and computational simplicities. The advantages of employing triangular IFNs in fuzzy modeling and interpreting have been well-justified for MCDM problems [18]. According to Zadeh [22], a fuzzy set M in $X = \{x\}$ is given by $M = \{< x, \mu_M(x) > | x \in X\}$, where $\mu_M : X \to [0, 1]$ is the membership function of the fuzzy set M; $\mu_M(x) \in [0, 1]$ is the membership of $x \in X$ in M. The figure for membership functions of linguistic variables for ratings under the qualitative evaluation criteria are shown in Fig. 55.3.

Evaluators also make judgments on the importance of all criteria. Similarly, ratings of criteria importance are expressed as triangular IFNs as shown in Table 55.2 and their membership functions are shown in Fig. 55.3.

According to Szmidt [16], for two intuitionistic fuzzy sets A and B in $X = \{x_d, d = 1, \ldots, D\}$, their Euclidean distance is equal to:

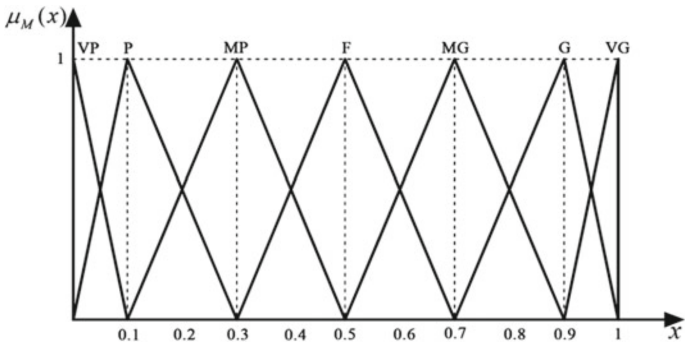


Fig. 55.3 Figure for membership functions of linguistic variables of ratings under the FSQ evaluation criteria

Table 55.2 Linguistic variables and triangular IFNs for rating the importance

Linguistic variables	Intuitionistic fuzzy number
Very high (VH)	(0.7, 0.9, 1.0)
High (H)	(0.6, 0.7, 0.8)
Medium high (MH)	(0.4, 0.5, 0.6)
Medium (M)	(0.1, 0.3, 0.5)
Medium low (ML)	(0.1, 0.2, 0.3)
Low (L)	(0.0, 0.1, 0.2)
Very low (VL)	(0.0, 0.0, 0.2)

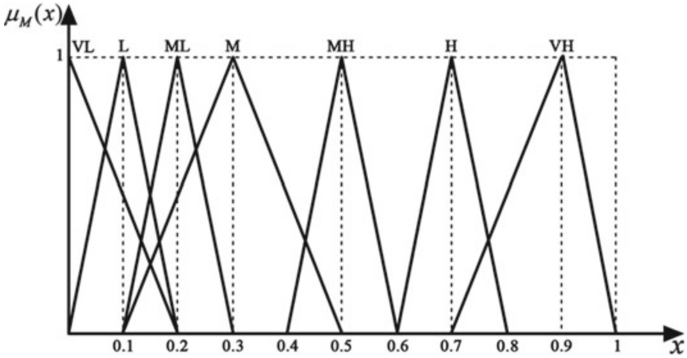


Fig. 55.4 Figure for membership functions of linguistic variables for ratings the importance

$$\mathrm{eIFS}(A, B) = \sqrt{\sum_{d=1}^{D}\left[(\mu_A(x_d) - \mu_B(x_d))^2 + (\nu_A(x_d) - \nu_B(x_d))^2 + (\pi_A(x_d) - \pi_B(x_d))^2\right]}, \tag{55.1}$$

where $A = (\mu_A(x_d), \nu_A(x_d), \pi_A(x_d))$, $B = (\mu_B(x_d), \nu_B(x_d), \pi_B(x_d))$ (Fig. 55.4).

Let $z_{ikj} = (\mu_{ikj}, \nu_{ikj}, \pi_{ikj}), (i = 1, 2, \ldots, p;\ j = 1, \ldots, 4;\ k = 1, 2, \ldots, n)$ denote the ratings of all companies's annual financial statements under the qualitative evaluation criteria, and $z_{ij}^{'} = (\mu_{ij}^{'}, \nu_{ij}^{'}, \pi_{ij}^{'})(i = 1, 2, \ldots, p;\ j = 1, \ldots, 4)$ denote the importance rating of all criteria. These ratings with evaluator weights can be expressed as $\bar{z}_{ikj} = w_i^E z_{ikj} = (w_i^E \mu_{ikj}, w_i^E \nu_{ikj}, w_i^E \pi_{ikj})$ and $\bar{z}_{ij}^{'} = w_i^E z_{ij}^{'} = (w_i^E \mu_{ij}^{'}, w_i^E \nu_{ij}^{'}, w_i^E \pi_{ij}^{'}), (i = 1, 2, \ldots, p;\ j = 1, \ldots, 4;\ k = 1, 2, \ldots, n)$. The sum of the Euclidean distance from one evaluator's ratings to another regarding companies' annual financial statements for qualitative evaluation criteria can be expressed as:

$$\sum_{i=1}^{p}\sum_{l=1, l\neq i}^{p}\sum_{j=1}^{4}\sum_{k=1}^{n}\mathrm{eIFS}(\bar{z}_{ikj}, \bar{z}_{lkj}).$$

Similarly, the sum of the Euclidean distance from one evaluator's ratings to another regarding criteria importance can be expressed as:

$$\sum_{i=1}^{p}\sum_{l=1, l\neq i}^{p}\sum_{j=1}^{4}\mathrm{eIFS}(\bar{z}_{ij}^{'}, \bar{z}_{lj}^{'}).$$

To determine the best $w_i^E (i = 1, \ldots, p)$ for the maximum agreement, all ratings with weights of evaluators should move towards one another. This is the principle on the basis of which an aggregated evaluation result is generated. Based on the above analysis, we establish the optimization model which minimizes the sum of the Euclidean distances between all pairs of evaluation results with weights of evaluators:

$$\min_{w_i^E} D = \sum_{i=1}^{p} \sum_{l=1,l\neq i}^{p} \sum_{j=1}^{4} \sum_{k=1}^{n} \mathrm{eIFS}(\bar{z}_{ikj}, \bar{z}_{lkj}) + \sum_{i=1}^{p} \sum_{l=1,l\neq i}^{p} \sum_{j=1}^{4} \mathrm{eIFS}(\bar{z}'_{ij}, \bar{z}'_{lj})$$

$$s.t. \begin{cases} \bar{z}_{ikj} = w_i^E z_{ikj} = (w_i^E \mu_{ikj}, w_i^E \nu_{ikj}, w_i^E \pi_{ikj}) \\ (i = 1, 2, \ldots, p;\ j = 1, \ldots, 4;\ k = 1, 2, \ldots, n) \\ \bar{z}_{lkj} = w_i^E z_{lkj} = (w_i^E \mu_{lkj}, w_i^E \nu_{lkj}, w_i^E \pi_{lkj}) \\ (l = 1, 2, \ldots, p, l \neq i;\ j = 1, \ldots, 4;\ k = 1, 2, \ldots, n) \\ \bar{z}'_{ij} = w_i^E z'_{ij} = (w_i^E \mu'_{ij}, w_i^E \nu'_{ij}, w_i^E \pi'_{ij}) \\ (i = 1, 2, \ldots, p;\ j = 1, \ldots, 4) \\ \bar{z}'_{lj} = w_i^E z'_{lj} = (w_i^E \mu'_{lj}, w_i^E \nu'_{lj}, w_i^E \pi'_{lj}) \\ (l = 1, 2, \ldots, p, l \neq i;\ j = 1, \ldots, 4) \\ \sum_{i=1}^{p} w_i^E = 1, \\ w_i^E \geq 0, i = 1, \ldots, p. \end{cases} \tag{55.2}$$

As discussed in the last section, the criteria importance are rated by evaluators using triangular IFNs, which is expressed by $z'_{ij} = (\mu'_{ij}, \nu'_{ij}, \pi'_{ij})$, $(i = 1, 2, \ldots, p;\ j = 1, \ldots, 4)$. In this paper, an intuitionistic fuzzy weighted averaging operator proposed by Xu [21] is utilized to aggregate all evaluator opinions on criteria importance into a group opinion. Considering evaluators' weights $W^E = \{w_i^E, i = 1, \ldots, p\}$ obtained by Eq. (55.2), the weight of the jth criteria can be obtained by:

$$w_j^C = \frac{\bar{\mu}'_j + \bar{\pi}'_j \left(\frac{\bar{\mu}'_j}{\bar{\mu}'_j + \bar{\nu}'_j} \right)}{\sum_{j=1}^{4} \left[\bar{\mu}'_j + \bar{\pi}'_j \left(\frac{\bar{\mu}'_j}{\bar{\mu}'_j + \bar{\nu}'_j} \right) \right]}, \tag{55.3}$$

where

$$\bar{\mu}'_j = \sum_{i=1}^{p} w_i^E \mu'_{ij}, \quad \bar{\nu}'_j = \sum_{i=1}^{p} w_i^E \nu'_{ij}, \quad \bar{\pi}'_j = \sum_{i=1}^{p} w_i^E \pi'_{ij}, \text{ and } \sum_{j=1}^{4} w_j^C = 1. \tag{55.4}$$

From Eqs. (55.3) and (55.4), criteria weights can be decided by the linguistic description of the criteria's importance and evaluators' weights.

55.3.4 Aggregation Method

Next task is to aggregate evaluation results from different evaluators into an integrated group consensus. Let $X = \Psi(Z_1, Z_2, \ldots, Z_p)$ denote the aggregation of p evaluators' results, where $\Psi(\cdot)$ is an aggregation function. $Z_i (i = 1, \ldots, p)$ is a $n \times 4$ matrix denoting the ith evaluator's rating of n companies's FSQ under 4 criteria. In this paper we use a common linear additive procedure, so for the qualitative evaluation criteria of financial statements:

$$\tilde{x}_{kj} = \sum_{i=1}^{p} w_i^E Z_i = \sum_{i=1}^{p} w_i^E z_{ikj} = \sum_{i=1}^{p} \left(w_i^E \mu_{ikj}, w_i^E \nu_{ikj}, w_i^E \pi_{ikj}\right) = (\mu_{kj}, \nu_{kj}, \pi_{kj})$$
$$\tilde{x}_{kj} \in X, (k = 1, \ldots, n; j = 1, \ldots, 4), \tag{55.5}$$

where, $\tilde{\cdot}$ is a fuzzyness notation. The fuzzy multi-criteria evaluation of FSQ can be expressed in the matrix format as:

$$X = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \tilde{x}_{13} & \tilde{x}_{14} \\ \tilde{x}_{21} & \tilde{x}_{22} & \tilde{x}_{23} & \tilde{x}_{24} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{n1} & \tilde{x}_{n2} & \tilde{x}_{n3} & \tilde{x}_{n4} \end{bmatrix}. \tag{55.6}$$

In order to aggregate ratings of companies' annual financial statements for each criteria, we use the TOPSIS concept. As well known, TOPSIS takes advantage of the positive-ideal solution (PIS) and the negative-ideal solution (NIS) of multi-attribute problems to rank the plan sets. The procedure of the extended TOPSIS method used in this paper is described as follows:

Step 1. Compute the normalized decision matrix. Vector normalization is applied to calculate r_{kj} and $\tilde{r}_{kj}$.

$$r_{kj} = \frac{x_{kj}}{\sqrt{\sum_{k=1}^{n} x_{kj}^2}}, \quad k = 1, 2, \ldots, n; \ j = 1, \ldots, 4, \tag{55.7}$$

$$\tilde{r}_{kj} = \left(\frac{\mu_{kj}}{d_j^*}, \frac{\nu_{kj}}{d_j^*}, \frac{\pi_{kj}}{d_j^*}\right), \quad k = 1, 2, \ldots, n; \ j = 1, \ldots, 4, \tag{55.8}$$

$$d_j^* = \sqrt{\sum_{k=1}^{n} \pi_{kj}^2}. \tag{55.9}$$

Step 2. Construct the weighted and normalized evaluation matrix V:

$$V = \begin{bmatrix} \tilde{v}_{11} & \tilde{v}_{12} & \tilde{v}_{13} & \tilde{v}_{14} \\ \tilde{v}_{21} & \tilde{v}_{22} & \tilde{v}_{23} & \tilde{v}_{24} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{v}_{n1} & \tilde{v}_{n2} & \tilde{v}_{n3} & \tilde{v}_{n4} \end{bmatrix} = \begin{bmatrix} w_1^C \tilde{r}_{11} & w_2^C \tilde{r}_{12} & w_3^C \tilde{r}_{13} & w_4^C \tilde{r}_{14} \\ w_1^C \tilde{r}_{21} & w_2^C \tilde{r}_{22} & w_3^C \tilde{r}_{23} & w_4^C \tilde{r}_{24} \\ \vdots & \vdots & \vdots & \vdots \\ w_1^C \tilde{r}_{n1} & w_2^C \tilde{r}_{n2} & w_3^C \tilde{r}_{n3} & w_4^C \tilde{r}_{n4} \end{bmatrix} \tag{55.10}$$

Step 3. Determine the PIS and NIS. All criteria in this paper are benefit criteria, therefore, the values of PIS (A^+) and NIS (A^-) are defined as:

$$A^+ = \{\max_k v_{kj} | j = 1, \ldots, 4\} = (\tilde{v}_1^+, \tilde{v}_2^+, \tilde{v}_3^+, \tilde{v}_4^+); \tag{55.11}$$

$$A^- = \{\min_k v_{kj} | j = 1, \ldots, 4\} = (\tilde{v}_1^-, \tilde{v}_2^-, \tilde{v}_3^-, \tilde{v}_4^-). \tag{55.12}$$

A^+ and A^- indicate the most and the least preferable FSQ of companies, respectively. For all k and $j = 1, \ldots, 4$, let $\tilde{v}_{kj} = (a_{kj}, b_{kj}, c_{kj})$, $\tilde{v}_j^+ = (a_j^+, b_j^+, c_j^+)$, and $\tilde{v}_j^- = (a_j^-, b_j^-, c_j^-)$ where $a_j^+ = \max_k a_{kj}$, $b_j^+ = \max_k b_{kj}$, $c_j^+ = \max_k c_{kj}$, $a_j^- = \min_k a_{kj}$, $b_j^- = \min_k b_{kj}$, and $c_j^- = \min_k c_{kj}$.

Step 4. Calculate the Euclidean distance. The Euclidean distance between each company's FSQ and A^+ is:

$$S_k^+ = \sqrt{\sum_{j=1}^{j=4} \left[(a_{kj} - a_j^+)^2 + (b_{kj} - b_j^+)^2 + (c_{kj} - c_j^+)^2\right]}, k = 1, 2, \ldots, n. \tag{55.13}$$

Similarly, the Euclid distance between each company's FSQ and A^- is:

$$S_k^- = \sqrt{\sum_{j=1}^{j=4} [(a_{kj} - a_j^-)^2 + (b_{kj} - b_j^-)^2 + (a_{kj} - c_j^-)^2]}, k = 1, 2, \ldots, n. \tag{55.14}$$

Step 5. Calculate the relative closeness of each company's FSQ to A^+:

$$R_k^+ = \frac{S_k^-}{S_k^+ + S_k^-}, 0 < C_k^+ < 1, k = 1, 2, \ldots, n. \tag{55.15}$$

Step 6. Rank the preference order. By ordering R_k^+ in descending order, the quality of companies' annual financial statements can be ranked from the best to the worst. R_k^+ can serve as the evaluation score of company A_k's annual financial statement quality.

55.4 Case Solution

As discussed above, the evaluator's ratings of the qualitative evaluation criteria in Table 55.3 can be expressed as triangular IFNs z_{ikj} ($i = 1, \ldots, 5$; $k = 1, \ldots, 10$; $j = 1, \ldots, 4$) as shown in Tables 55.5, 55.6, 55.7 and 55.8. Similarly, triangular IFNs of evaluator's ratings of criteria importance $\tilde{z}_{ij}$ ($i = 1, \ldots, 5$; $j = 1, \ldots, 4$) can be seen in Table 55.4. According to model (55.2), we can get evaluators' weights $W^E =$

Table 55.3 Ratings of companies' annual financial statements under qualitative evaluation criteria

Criteria	Companies	E_1	E_2	E_3	E_4	E_5	Criteria	Companies	E_1	E_2	E_3	E_4	E_5
C_1	A_1	VG	VP	F	VP	G	C_2	A_1	F	P	VG	MP	F
	A_2	MG	G	MP	F	G		A_2	MG	P	VG	MG	MG
	A_3	F	MG	MP	P	G		A_3	MG	MP	F	P	MG
	A_4	G	MG	P	MP	G		A_4	P	F	F	MP	MP
	A_5	VP	MG	VG	MG	MG		A_5	VG	F	F	F	MP
	A_6	P	VP	F	VP	VP		A_6	G	VG	VG	F	MP
	A_7	G	VP	F	VP	VG		A_7	VP	VG	G	F	G
	A_8	VG	VP	VP	VP	P		A_8	F	VG	VG	VP	VP
	A_9	MG	G	P	P	MG		A_9	VG	VG	F	VP	P
	A_{10}	MG	F	P	P	VG		A_{10}	VG	G	VP	VP	MP
C_3	A_1	VP	G	VG	F	MG	C_4	A_1	VG	VP	MG	VG	VG
	A_2	VP	MG	MG	F	MG		A_2	VG	VP	VP	P	VG
	A_3	VG	F	F	G	VP		A_3	VG	P	VP	F	P
	A_4	VG	VP	G	P	VP		A_4	G	P	G	G	F
	A_5	G	VP	P	P	MP		A_5	G	F	G	MG	VP
	A_6	VP	P	MG	VP	MP		A_6	VP	F	G	P	VG
	A_7	MG	G	MP	VP	VP		A_7	VP	G	F	G	G
	A_8	VP	G	MG	F	VP		A_8	MG	VP	F	MP	G
	A_9	P	VP	F	VP	MG		A_9	MG	P	VP	MG	MG
	A_{10}	P	F	MG	VP	MG		A_{10}	MG	MP	MG	MG	MG

Table 55.4 Importance ratings and triangular IFNs of all criteria

Criteria	Companies				
	E_1 $(\mu'_{1j}, \nu'_{1j}, \pi'_{1j})$	E_2 $(\mu'_{2j}, \nu'_{2j}, \pi'_{2j})$	E_3 $(\mu'_{3j}, \nu'_{3j}, \pi'_{3j})$	E_4 $(\mu'_{4j}, \nu'_{4j}, \pi'_{4j})$	E_5 $(\mu'_{5j}, \nu'_{5j}, \pi'_{5j})$
C_1	H (0.6, 0.7, 0.8)	MH (0.4, 0.5, 0.6)	ML (0.1, 0.2, 0.3)	M (0.1, 0.3, 0.5)	M (0.1, 0.3, 0.5)
C_2	VH (0.7, 0.9, 1.0)	H (0.6, 0.7, 0.8)	VH (0.7, 0.9, 1.0)	MH (0.4, 0.5, 0.6)	H (0.6, 0.7, 0.8)
C_3	ML (0.1, 0.2, 0.3)	MH (0.4, 0.5, 0.6)	M (0.1, 0.3, 0.5)	H (0.6, 0.7, 0.8)	MH (0.4, 0.5, 0.6)
C_4	MH (0.4, 0.5, 0.6)	H (0.6, 0.7, 0.8)	ML (0.1, 0.2, 0.3)	VH (0.7, 0.9, 1.0)	VH (0.7, 0.9, 1.0)

Table 55.5 Triangular IFNs of evaluators' ratings under C_1

Companies	z_{1k3}			z_{2k3}			z_{3k3}			z_{4k3}			z_{5k3}		
A_1	0.9	1	1	0	0	0.1	0.3	0.5	0.7	0	0	0.1	0.7	0.9	1
A_2	0.5	0.7	0.9	0.7	0.9	1	0.1	0.3	0.5	0.3	0.5	0.7	0.7	0.9	1
A_3	0.3	0.5	0.7	0.5	0.7	0.9	0.1	0.3	0.5	0	0.1	0.3	0.7	0.9	1
A_4	0.7	0.9	1	0.5	0.7	0.9	0	0.1	0.3	0.1	0.3	0.5	0.7	0.9	1
A_5	0	0	0.1	0.5	0.7	0.9	0.9	1	1	0.5	0.7	0.9	0.5	0.7	0.9
A_6	0	0.1	0.3	0	0	0.1	0.3	0.5	0.7	0	0	0.1	0	0	0.1
A_7	0.7	0.9	1	0	0	0.1	0.3	0.5	0.7	0	0	0.1	0.9	1	1
A_8	0.9	1	1	0	0	0.1	0	0	0.1	0	0	0.1	0	0.1	0.3
A_9	0.5	0.7	0.9	0.7	0.9	1	0	0.1	0.3	0	0.1	0.3	0.5	0.7	0.9
A_{10}	0.5	0.7	0.9	0.3	0.5	0.7	0	0.1	0.3	0	0.1	0.3	0.9	1	1

Table 55.6 Triangular IFNs of evaluators' ratings under C_2

Companies	z_{1k3}			z_{2k3}			z_{3k3}			z_{4k3}			z_{5k3}		
A_1	0.3	0.5	0.7	0	0.1	0.3	0.9	1	1	0.1	0.3	0.5	0.3	0.5	0.7
A_2	0.5	0.7	0.9	0	0.1	0.3	0.9	1	1	0.5	0.7	0.9	0.5	0.7	0.9
A_3	0.5	0.7	0.9	0.1	0.3	0.5	0.3	0.5	0.7	0	0.1	0.3	0.5	0.7	0.9
A_4	0	0.1	0.3	0.3	0.5	0.7	0.3	0.5	0.7	0.1	0.3	0.5	0.1	0.3	0.5
A_5	0.9	1	1	0.3	0.5	0.7	0.3	0.5	0.7	0.3	0.5	0.7	0.1	0.3	0.5
A_6	0.7	0.9	1	0.9	1	1	0.9	1	1	0.3	0.5	0.7	0.1	0.3	0.5
A_7	0	0	0.1	0.9	1	1	0.7	0.9	1	0.3	0.5	0.7	0.7	0.9	1
A_8	0.3	0.5	0.7	0.9	1	1	0.9	1	1	0	0	0.1	0	0	0.1
A_9	0.9	1	1	0.9	1	1	0.3	0.5	0.7	0	0	0.1	0	0.1	0.3
A_{10}	0.9	1	1	0.7	0.9	1	0	0	0.1	0	0	0.1	0.1	0.3	0.5

Table 55.7 Triangular IFNs of evaluators' ratings under C_3

Companies	z_{1k3}			z_{2k3}			z_{3k3}			z_{4k3}			z_{5k3}		
A_1	0	0	0.1	0.7	0.9	1	0.9	1	1	0.3	0.5	0.7	0.5	0.7	0.9
A_2	0	0	0.1	0.5	0.7	0.9	0.5	0.7	0.9	0.3	0.5	0.7	0.5	0.7	0.9
A_3	0.9	1	1	0.3	0.5	0.7	0.3	0.5	0.7	0.7	0.9	1	0	0	0.1
A_4	0.9	1	1	0	0	0.1	0.7	0.9	1	0	0.1	0.3	0	0	0.1
A_5	0.7	0.9	1	0	0	0.1	0	0.1	0.3	0	0.1	0.3	0.1	0.3	0.5
A_6	0	0	0.1	0	0.1	0.3	0.5	0.7	0.9	0	0	0.1	0.1	0.3	0.5
A_7	0.5	0.7	0.9	0.7	0.9	1	0.1	0.3	0.5	0	0	0.1	0	0	0.1
A_8	0	0	0.1	0.7	0.9	1	0.5	0.7	0.9	0.3	0.5	0.7	0	0	0.1
A_9	0	0.1	0.3	0	0	0.1	0.3	0.5	0.7	0	0	0.1	0.5	0.7	0.9
A_{10}	0	0.1	0.3	0.3	0.5	0.7	0.5	0.7	0.9	0	0	0.1	0.5	0.7	0.9

Table 55.8 Triangular IFNs of evaluators' ratings under C_4

Companies	z_{1k3}			z_{2k3}			z_{3k3}			z_{4k3}			z_{5k3}		
A_1	0.9	1	1	0	0	0.1	0.5	0.7	0.9	0.9	1	1	0.9	1	1
A_2	0.9	1	1	0	0	0.1	0	0	0.1	0	0.1	0.3	0.9	1	1
A_3	0.9	1	1	0	0.1	0.3	0	0	0.1	0.3	0.5	0.7	0	0.1	0.3
A_4	0.7	0.9	1	0	0.1	0.3	0.7	0.9	1	0.7	0.9	1	0.3	0.5	0.7
A_5	0.7	0.9	1	0.3	0.5	0.7	0.7	0.9	1	0.5	0.7	0.9	0	0	0.1
A_6	0	0	0.1	0.3	0.5	0.7	0.7	0.9	1	0	0.1	0.3	0.9	1	1
A_7	0	0	0.1	0.7	0.9	1	0.3	0.5	0.7	0.7	0.9	1	0.7	0.9	1
A_8	0.5	0.7	0.9	0	0	0.1	0.3	0.5	0.7	0.1	0.3	0.5	0.7	0.9	1
A_9	0.5	0.7	0.9	0	0.1	0.3	0	0	0.1	0.5	0.7	0.9	0.5	0.7	0.9
A_{10}	0.5	0.7	0.9	0.1	0.3	0.5	0.5	0.7	0.9	0.5	0.7	0.9	0.5	0.7	0.9

$(0.159, 0.203, 0.188, 0.267, 0.183)$. Because the optimization model minimizes the sum of the Euclidean distances between all pairs of qualitative ratings represented by IFNs, the obtained W^E guarantees the maximum agreement/consensus of evaluation results.

According to Eq. (55.4) and Table 55.4,

$$\bar{\mu}'_j = \sum_{i=1}^{p} w_i^E \mu'_{ij} = 0.159 \times \begin{pmatrix} 0.6 \\ 0.7 \\ 0.1 \\ 0.4 \end{pmatrix} + 0.203 \times \begin{pmatrix} 0.4 \\ 0.6 \\ 0.4 \\ 0.6 \end{pmatrix} + 0.188 \times \begin{pmatrix} 0.1 \\ 0.7 \\ 0.1 \\ 0.1 \end{pmatrix}$$
$$+ 0.267 \times \begin{pmatrix} 0.1 \\ 0.4 \\ 0.6 \\ 0.7 \end{pmatrix} + 0.183 \times \begin{pmatrix} 0.1 \\ 0.6 \\ 0.4 \\ 0.7 \end{pmatrix} = \begin{pmatrix} 0.2404 \\ 0.5813 \\ 0.2493 \\ 0.5192 \end{pmatrix},$$

Table 55.9 Evaluation results with different R_k^+ and $R_k^{'+}$ ranks given in bold face

Companies	S_k^+	S_k^-	R_k^+	Rank by R_k^+	Rank by $R_k^{'+}$
A_1	0.0697	0.1310	2.0119	2	2
A_2	0.0789	0.1218	1.6647	3	3
A_3	0.1165	0.0898	0.8602	8	8
A_4	0.1134	0.0978	0.9608	**6**	**7**
A_5	0.0874	0.1034	1.2862	4	4
A_6	0.1171	0.1073	1.0239	5	5
A_7	0.0624	0.1183	2.0147	1	1
A_8	0.1104	0.0699	0.7033	10	10
A_9	0.1124	0.0756	0.7480	9	9
A_{10}	0.0956	0.0934	1.0709	**7**	**6**

$$\bar{\nu}'_j = \sum_{i=1}^{p} w_i^E \nu'_{ij} = 0.159 \times \begin{pmatrix} 0.7 \\ 0.9 \\ 0.2 \\ 0.5 \end{pmatrix} + 0.203 \times \begin{pmatrix} 0.5 \\ 0.7 \\ 0.5 \\ 0.7 \end{pmatrix} + 0.188 \times \begin{pmatrix} 0.2 \\ 0.9 \\ 0.3 \\ 0.2 \end{pmatrix}$$

$$+ 0.267 \times \begin{pmatrix} 0.3 \\ 0.5 \\ 0.7 \\ 0.9 \end{pmatrix} + 0.183 \times \begin{pmatrix} 0.3 \\ 0.7 \\ 0.5 \\ 0.9 \end{pmatrix} = \begin{pmatrix} 0.3854 \\ 0.7160 \\ 0.4681 \\ 0.6642 \end{pmatrix},$$

$$\bar{\pi}'_j = \sum_{i=1}^{p} w_i^E \pi'_{ij} = 0.159 \times \begin{pmatrix} 0.8 \\ 1.0 \\ 0.3 \\ 0.6 \end{pmatrix} + 0.203 \times \begin{pmatrix} 0.6 \\ 0.8 \\ 0.6 \\ 0.8 \end{pmatrix} + 0.188 \times \begin{pmatrix} 0.3 \\ 1.0 \\ 0.5 \\ 0.3 \end{pmatrix}$$

$$+ 0.267 \times \begin{pmatrix} 0.5 \\ 0.6 \\ 0.8 \\ 1.0 \end{pmatrix} + 0.183 \times \begin{pmatrix} 0.5 \\ 0.8 \\ 0.6 \\ 1.0 \end{pmatrix} = \begin{pmatrix} 0.5304 \\ 0.8160 \\ 0.5869 \\ 0.7642 \end{pmatrix}.$$

Based on Eq. (55.3), we obtain the weights of criteria $W^C = (0.156, 0.333, 0.211, 0.300)^T$. Subsequently, by Eqs. (55.5) and (55.6), the evaluation matrix X is obtained:

$$X = \begin{bmatrix} (0.3280, 0.4182, 0.5211) & (0.2988, 0.4597, 0.6220) & (0.4829, 0.6322, 0.7584) & (0.6424, 0.7410, 0.7988) \\ (0.4486, 0.6486, 0.810) & (0.4740, 0.6349, 0.7973) & (0.3671, 0.5352, 0.7193) & (0.3082, 0.3691, 0.4616) \\ \vdots & \vdots & \vdots & \vdots \\ (0.3053, 0.4415, 0.6048) & (0.3034, 0.3965, 0.4989) & (0.2465, 0.3772, 0.5506) & (0.419, 0.619, 0.819) \end{bmatrix}.$$

From Eqs. (55.7)–(55.10), we get the weighted and normalized evaluation matrix V:

$$V = \begin{bmatrix} (0.0262, 0.034, 0.0424) & (0.0475, 0.0731, 0.099) & (0.0573, 0.075, 0.0899) & (0.0885, 0.1021, 0.1101) \\ (0.0365, 0.0527, 0.0659) & (0.0754, 0.101, 0.1268) & (0.0435, 0.0635, 0.0853) & (0.0425, 0.0509, 0.0636) \\ \vdots & \vdots & \vdots & \vdots \\ (0.0248, 0.0359, 0.0492) & (0.0483, 0.0631, 0.0794) & (0.0292, 0.0447, 0.0653) & (0.0577, 0.0853, 0.1129) \end{bmatrix}.$$

Therefore, A^+ and A^- can be easily obtained: $A^+ = \{\max_k v_{kj} | j = 1, \ldots, 4\} = ((0.0403, 0.0527, 0.0659), (0.0893, 0.1149, 0.1318), (0.0573, 0.075, 0.0899), (0.0885, 0.1021, 0.1129))^T$; $A^- = \{\min_k v_{kj} | j = 1, \ldots, 4\} = ((0.0046, 0.0089, 0.0199), (0.0258, 0.0551, 0.0794), (0.0133, 0.0245, 0.0432), (0.0308, 0.0456, 0.0636))^T$.

By Eqs. (55.13)–(55.15), S_k^+, S_k^- and R_k^+ are determined and the ten companies' annual financial statements quality ranked as shown in Table 55.9.

55.4.1 Discussion

FSQ of these ten companies' financial statements are sorted from the best to the worst by the proposed method as shown in Table 55.9. In this section we discuss the effectiveness of the proposed methodology and compare it with former research.

We recalculate the problem given equal weights to five evaluators, namely $w_i^{'E} = 0.2, i = 1, \ldots, 5$. In this situation, $W^{'C} = (0.1940, 2.1426, 1.7923, 2.1763)$. The rank by $R_k^{'+}$ column in Table 55.9 shows the ranks of ten companies' annual financial reports with evaluators given equal weights. As shown in Table 55.9, two companies' annual financial reports are ranked differently by R_k^+ and $R_k^{'+}$. The rankings by R_k^+ column in Table 55.9 represents the maximum consensus evaluation. In this sense, the database is relatively small within ten financial statements so the results of ranking by R_k^+ and ranking by $R_k^{'+}$ are not very different.

55.5 Conclusion

Companies, corporations, economic groups and research departments are facing with demands for higher financial reporting quality and the consequences of exiting gaps in audit processing. FSQ evaluation is useful and significant for decision making process in business. The financial reports must be relevant, reliable, comparable, and understandable, which constitute the evaluating index system of FSQ. To conquer the weighting difficulty, this paper develops an intuitionistic fuzzy weighted averaging operator for weighting criteria, and a fuzzy distance-based method for weighting evaluators' judgements. Considering the inevitable subjective judgments and preferences in FSQ evaluation, this paper further extends the aggregation method to fuzzy environment. Finally, a case study with actual data was conducted to test the feasibility and effectiveness of the proposed method. Compared with the results of arbitrary weights of evaluators, the results from this paper represent the maximum agreement results; therefore, it is more persuasive.

Due to the complexity of FSQ evaluation, the following are areas for our future research: (1) different qualitative evaluation criteria for different companies' annual financial reports in different fiscal years; (2) different qualitative evaluation criteria for different kinds of financial reports; (3) and better understanding and presentation of subjective information.

Acknowledgments The authors would like to express to their gratitude to Mrs. Nguyen Thi Van Oanh who is the Deputy Manager of Finance and Accounting Department of Duc Giang Corporation, Hanoi, Vietnam, for her cooperation. We are thankful for financial support from the program of China Scholarships Council (Grant No. 201206240126), and the Scientific Research Staring Foundation of Sichuan University (Grant No. 2015SCU11034).

References

1. Abbas S, Saeed B (2012) The effect of the consolidated financial statements on decision making. Am J Sci Res 6:37–50
2. Abdullah L (2013) Fuzzy multi criteria decision making and its applications: a brief review of category. Procedia-Soc Behav Sci 97:131–136
3. Alexander D, Nobes C (2007) Financial accounting: an international introduction, 3rd edn. Financial Times Prentice Hall, New Jersey
4. Atanassov KT (1986) Intuitionistic fuzzy sets. Fuzzy Sets Syst 20(1):87–96
5. Braam G, van Beest F (2013) Conceptually-based financial reporting quality assessment. An empirical analysis on quality differences between UK annual reports and US 10-K reports. Technical report, Working Paper
6. El-Wahed WFA (2008) Intelligent fuzzy multi-criteria decision making: review and analysis. In: Fuzzy multi-criteria decision making. Springer, pp 19–50
7. Habib A, Jiang H (2015) Corporate governance and financial reporting quality in China: a survey of recent evidence. J Int Account Audit Tax 24:29–45
8. Iatridis G (2010) International financial reporting standards and the quality of financial statement information. Int Rev Financ Anal 19(3):193–204
9. Li Z, Liechty M, Xu J, Lev B (2014) A fuzzy multi-criteria group decision making method for individual research output evaluation with maximum consensus. Knowledge-Based Syst 56:253–263
10. Lin WC, Liao TL (2015) Exchange listing type and firm financial reporting behavior. Int Rev Econ Financ 38:234–249
11. Ma J, Lu J, Zhang G (2010) Decider: a fuzzy multi-criteria group decision support system. Knowledge-Based Syst 23(1):23–31
12. Mardani A, Jusoh A, Zavadskas EK (2015) Fuzzy multiple criteria decision-making techniques and applications-two decades review from 1994 to 2014. Expert Syst Appl 42(8):4126–4148
13. Palea V (2013) IAS/IFRS and financial reporting quality: lessons from the European experience. China J Account Res 6(4):247–263
14. Peecher ME (2002) Discussion of evaluating financial reporting quality: the effects of financial expertise vs. financial literacy. Account Rev 77(s-1):169–173
15. Shaw A, Roy T (2013) Trapezoidal intuitionistic fuzzy number with some arithmetic operations and its application on reliability evaluation. Int J Math Oper Res 5(1):55–73

16. Szmidt E, Kacprzyk J (2000) Distances between intuitionistic fuzzy sets. Fuzzy Sets Syst 114(3):505–518
17. Tasios S, Bekiaris M (2012) Auditor's perceptions of financial reporting quality: the case of greece. Int J Account Financ Report 2(1):57
18. Vahdani B, Mousavi SM, Hashemi H, Mousakhani M, Tavakkoli-Moghaddam R (2013) A new compromise solution method for fuzzy group decision-making problems with an application to the contractor selection. Eng Appl Artif Intell 26(2):779–788
19. Van Beest F, Braam G, Boelens S (2009) Quality of financial reporting: measuring qualitative characteristics. Nijmegen Center for Economics (NiCE) Working Paper pp 09–108
20. Wahab EAA, Gist WE, Majid WZNA (2014) Characteristics of non-audit services and financial restatements in Malaysia. J Contemp Account Econ 10(3):225–247
21. Xu Z (2007) Intuitionistic fuzzy aggregation operators. IEEE Trans Fuzzy Syst 15(6):1179–1187
22. Zadeh LA (1965) Information and control. Fuzzy sets 8(3):338–353
23. Zadeh LA (1975) The concept of a linguistic variable and its application to approximate reasoningłi. Inf Sci 8(3):199–249
24. Zhang Sf, Liu Sy (2011) A gra-based intuitionistic fuzzy multi-criteria group decision making method for personnel selection. Expert Syst Appl 38(9):11401–11405

Chapter 56
Dynamic Programming Optimization Model of End-Stage Renal Disease

Kejia Wang, Xiaoxi Zeng, Muhammad Hashim and Liming Yao

Abstract The principal treatments for end stage renal disease (ESRD) are hemodialysis, peritoneal dialysis, and kidney transplantation, all of which have both advantages and disadvantages. The paper firstly quantifies ESRD patients' pre-treatment quality of life. Then, by using a series of state transition equations, it predicts patients' values of health-related quality of life (HRQoL) after they follow different treatment plans. Eventually, a dynamic programming model is established to determine the most cost-effective decision scheme.

Keywords End-stage renal disease · Optimal decision · Cost-effective analysis

56.1 Introduction

Due to a large population and a relatively low economic level, China had limited health resource per capita and yet a high incidence of chronic kidney disease. Nevertheless, since the 1980s, end-stage renal disease treatment technology has advanced considerably because of its economic development and the progress of medical science. Accordingly, kidney dialysis and renal transplantation have been successfully implemented. After surveying literature on treatment of ESRD and measurement

K. Wang
Business School, Sichuan University, Chengdu 610064, People's Republic of China

X. Zeng
Department of Nephrology, West China Hospital, Sichuan University,
Chengdu 610064, People's Republic of China

M. Hashim
Department of Business Administration, National Textile University,
Sheikhupura Road, Faisalabad 37610, Pakistan

L. Yao (✉)
Uncertainty Decision-Making Laboratory, Sichuan University,
Chengdu 610064, People's Republic of China
e-mail: lmyao@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_56

of life and health, the paper finds that in China, dialysis and renal transplantation were first conducted in Shanghai where nearly 1,000 patients received these two treatments. Some of them bore children and lived around 10 years longer than the ESRD patients who did not receive such treatments. Individuals with ESRD suffer both physically and mentally, since the treatment not only costs considerably but is accompanied by various complications as well. It is, therefore, of practical significance to determine a cost-effective treatment scheme for patients through analyzing their degrees of illness, health-related qualities of life and financial situations. For this reason, a decision optimization model is established [1].

Quality of life, redefined by the World Health Organization (WHO) in 1984, refers to "the perceived quality of a person's life; that is, an assessment of their living conditions regarding their goals, expectations, standards, and so forth. It includes all physical, emotional, and social aspects of the individual's life". Accordingly, quality of life is used to measure patients' health status. Nonetheless, scholars in different areas, based on their professionalism and understanding, present different concepts of quality of life. For the sociologists, quality of life refers to quality of individuals' well-being, since they emphasize the emotional and cognitive aspects of an individual. For medical scientists and ethicists, it has often been translated into quality of survival because they concern about bodily function and its impacts on normal life. Some scholars argue that "quality of life is patients' recognition and satisfaction of their current bodily function, indicating that their expectation is reached". Other scholars define quality of life as "an overall measurement of well-being regarding all physical, psychological, and social aspects perceived by an individual or a group, which can be represented by subjective well-being, satisfaction or gratification [4, 7]".

Given various aspects of quality of life, the WHO, hence, puts forwards a measurement of quality of life. It comprises six dimensions, namely physical function, mental status, independence, social relationship, living environment, as well as religious and spiritual beliefs, each of which contains different subitems. Overall, quality of life refers to a respondent's multidimensional concept of subjective feeling and one's self assessment based on their feelings, cultural backgrounds, and social values. Considering cultural dependency, quality of life should be measured under a certain cultural value system which provides the basis for the quality of life scale (QOLS) [5].

56.2 Problem Description

Two principal dialysis treatments available for patients with End-stage renal disease (ESRD) are hemodialysis (HD) and peritoneal dialysis (PD). Then, a brief introduction to the two treatments is presented below [6].

56.2.1 PD

Peritoneal dialysis, as a dialysis approach, has been gradually applied to the clinical treatment for kidney disease in the recent five decades. With the advancement of peritoneal dialysis technology, the dialysis connection system has been constantly updated, and a new peritoneal dialysis solution is developed in China. PD patients' quality of life, ability to work and their rate of return to society are improved. As a result, the number of PD patients is increasing. But the dropout rate of PD patients with end-stage renal failure is high. The most common complication of PD is peritonitis. With the advancement of technology, especially the improved connection system in recent years, the incidence of PD-related peritonitis has decreased significantly. But it still one of the principal factors preventing patients from PD [3].

56.2.2 HD

Compared with PD, HD, the world's most widely used replacement therapy, has manifold advantages, such as high dialysis performance and adequacy. Moreover, there are a large number of places where patients can easily get access to this medical treatment. Most importantly, individuals with kidney disease lose less protein provided that they choose HD. HD develops from a single hemodialysis approach to diverse and integrated treatments in China, including the blood purification therapy (Using methods such as hemodialysis, hemodiafiltration and hemoperfusion, blood purification therapy is applied to the treatment for acute and chronic renal failure). To sustain their lives, patients only need to receive HD two or three times a week regularly, without affecting their personal life. On the other hand, in terms of the shortcoming of HD, these patients die from cardiovascular complications most commonly [3].

The paper predicts the treatment costs (The costs of both HD and PD consist of dialysis cost, dialysate cost, hospitalization cost, and other expenses) of an individual patient by comprehensively considering the costs of both HD and PD as well as different reimbursement systems. Dialysis treatment costs = dialysis cost + hospitalization expenses − reimbursement for medical expense [3].

56.2.3 The Health Utility

Currently, both the survival rate and life quality are universally considered as the final evaluations of treatment schemes in the medical field. Dialysis treatment can prolong patients' life, but both patients and their families are increasingly concerned about their life quality [2].

Thus, the health utility value, a quantitative measure of life quality, is introduced in this section. It reflects people's preference for a particular health state, representing the value orientation of an individual or a society. Moreover, health utility value is used in Cost-utility analysis (CUA) (Cost-utility analysis is one of the economic evaluation methods measuring cost inputs and health outcomes) to calculate the weight of quality of life (QoL) in quality-adjusted life years (QALYs).

It can be found in some literature that a certain health state, sometimes, is worse than death; hence, the value range of health utility is between -1 to 1 where "1" represents full health while "0" denotes death. The worse a patient's health state, the lower the utility value. Therefore, the utility value becomes negative when a patient's health state is worse than death. Taking full health and death as references, the utility value of any non-full health reflects patients' degree of health preference. For instance, a patient suffers from kidney disease, accompanied by complications. If the health utility value of this patient is 0.2, it means that this person's degree of preference is only about one fifth of his/her full health preferences.

The paper chooses SF-6D (in Table 56.1) and the corresponding social value set (in Table 56.2) to measure ESRD patients' quality of life, utilizes the costs-utility analysis (CUA)to quantify the cost inputs and effect outputs of different treatments, and establishes a dynamic programming model to constrain costs and quality of life [5].

The SF-6D, derived from a selection of SF-36 items, is a classification and evaluation system of health status. It is composed of six multi-level dimensions and totally describes 18,000 health states [5].

56.2.4 Markov Model

Based on past academic research into this topic, given the availability of state transition probability, the paper utilizes Markov's theory to predict the state transition matrix of patients' quality of life. Designed for a state which has the properties of Markov stochastic process, Markov prediction can be used to determine the state transition probability matrix, thereby predicting the state of a system and its development trend. In this regard, it is a time sequence analysis. Meanwhile, Markov prediction is a scientific, accurate and highly adaptive prediction approach, playing a vital role in modern prediction methods. Additionally, it is widely applied to multiple fields such as economic administration, educational management, medicine and public health, and so forth.

The concept of Markov prediction: if a system, at time t_0, is in a certain state; then, at time $t > t_0$, the very state of this system is completely determined by its state at time t_0, and independent of its state at time $t < t_0$.

In treatment A, doctors have no strong preference for plan 1 or plan 2; that is, they should assume that there is no significant difference between plan 1 and 2. It can be achieved by constantly adjusting p. If "1" represents the utility of full recovery, while "0" denotes death; given $\lambda_1 = \lambda_2$, then $p = p_1$ is obtained (Fig. 56.1).

Table 56.1 The descriptive system of SF-6D

Dimensionality	Level	Description
Physical function	1	An individual's health allows him/her to do strenuous activities
	2	An individual is slightly constrained from doing strenuous activities due to his/her health state
	3	An individual is slightly constrained from doing moderate activities due to his/her health state
	4	An individual is largely constrained from doing moderate activities due to his/her health state
	5	An individual is slightly constrained from bathing and dressing due to his/her health state
	6	An individual is largely constrained from bathing and dressing due to his/her health state
Role limit	1	An individual does not have any physical or emotional problems affecting one's work and daily activities
	2	Physical problems restrict an individual's work and other activities
	3	Emotional problems restrict an individual's work
	4	Physical and emotional problems restrict an individual's work and other activities
Social function	1	An individual's health completely allows him/her to participate in social activities
	2	An individual's health seldom restricts his/her social activities
	3	An individual's health, sometimes, restricts his/her social activities
	4	An individual's health, for the most part, restricts his/her social activities
	5	An individual's health completely restricts his/her social activities
Pain	1	No pain
	2	There is pain, but it does not affect an individual's normal work (including outdoor work and housework)
	3	There is pain, but it just slightly affects an individual's normal work (including outdoor work and housework)
	4	There is pain which moderately affects an individual's normal work (including outdoor work and housework)
	5	There is pain which severely affects an individual's normal work (including outdoor work and housework)
	6	There is pain which disproportionately affects an individual's normal work (including outdoor work and housework)
Mental health	1	Never feel stressed or depressed
	2	Rarely feel stressed or depressed
	3	Sometimes feel stressed or depressed
	4	Most of the time feel stressed or depressed
	5	Always feel stressed or depressed
Vitality	1	Always feel energetic
	2	Most of the time feel energetic
	3	Sometimes feel energetic
	4	Rarely feel energetic
	5	Never feel energetic

Table 56.2 The value set for SF-6D

Level	PF	RL	SF	PAIN	MH	VIT
1	0	0	0	0	0	0
2	−0.053	−0.053	−0.055	−0.047	−0.049	−0.086
3	−0.011	−0.055	−0.067	−0.025	−0.042	−0.061
4	−0.04	−0.05	−0.07	−0.056	−0.109	−0.054
5	−0.054		−0.0.87	−0.091	−0.128	−0.091
6	−0.111			−0.167		

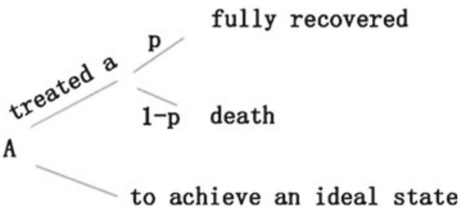


Fig. 56.1 Estimation of state transition probability with a full recovery and death as endpoints

$$p_i = \left[p_{i1}\, p_{i2}\, p_{i3}\, p_{i4}\, p_{i5}\, p_{i6}\right]. \tag{56.1}$$

p_{in}: the probability of rating n transformed from health-related quality of life of dimension in one treatment

56.3 Mathematical Model

The paper uses Markov model to simulate the change of ESRD patients' state of life, because each patient can only be in a certain health state, which is in line with the principles of establishing a Markov model. Moreover, SF-6D tariff is used in this study to determine the degree of the patient's life and health.

$$U = 1 + PF + RL + SF + \mathrm{PAIN} + MH + \mathrm{VIT} + \mathrm{MOST}. \tag{56.2}$$

MOST $= -0.016$ (this value should be added when one or more than one of these six dimensions is (or are) in the worst state. In other words, the value of the dimension (s) mentioned is a minimum).

When individuals make a decision, the U will change to U_i.

Both patients and doctors expect the maximum value of u, suggesting a desired quality of life

$$\Delta U = U_i - U, \tag{56.3}$$

$$U_i = U \times P_i. \tag{56.4}$$

U: The pre-treatment health utility value of patients.

U_i: The health utility value of patients after treatment.

p_i: State-transition Matrix.

An entire cost (C) function is presented below, and cost reduction is what patients expect. Hospitalization costs of end-stage chronic kidney disease includes different parts, such as surgery cost, dialysis cost, medication cost, bed and other hospital cost, and rehabilitation cost. All of them can be roughly grouped into three categories, namely hospitalization expenses, outpatient expenses, and other fees. Moreover, a patient's average annual dialysis cost is used as treatment cost in this model.

The objective function is to minimize $\frac{C_i}{\Delta U}$, thereby obtaining X.

C_i: Choose a treatment within total cost X_i.

56.4 Case Study

56.4.1 Basic Condition

Markov model can be adopted in this paper to predict the treatment cost and efficacy of ESRD, since the development and treatment of chronic diseases have Markov properties. Furthermore, the paper examines two dialysis treatments (namely, PD and HD) of a patient with chronic kidney disease when he has a certain initial health-related quality of life (HRQoL). Through comparing the differences between cost C effectiveness of the two treatments, the authors hope to provide more suitable decision-making suggestions for individuals with chronic diseases.

Dialysis treatment can extend the life of the patients, but its high cost is a heavy economic burden for their families. In China, numerous individuals with kidney disease have to afford this treatment and thus the improvement in their life quality is not as good as expected.

56.4.2 Case

A male patient Mr. Xu, 45 years old, diagnosed with end-stage renal disease in the West China hospital, Chengdu, fills in the following SF-6D tariff (in Table 56.3).

56.4.3 Counting Process

In accordance with $U = 1 + PF + RL + SF + \text{PAIN} + MH + \text{VIT} + \text{MOST}$.

$\text{MOST} = -0.016$ (this value should be added when one or more than one of these six dimensions is (or are) in the worst state. In other words, the value of the dimension(s) mentioned is a minimum).

Table 56.3 Patient Xu's SF-6D tariff before treatment

Dimensionality	Level	Value
PF	6	−0.111
RL	3	−0.055
SF	4	−0.07
PAIN	4	−0.056
MH	3	−0.042
VIT	4	−0.054

$$U = 1 + (-0.111) + (-0.055) + (-0.070) + (-0.056) + (-0.042) + (-0.054) + (-0.061) = 0.551.$$

Determine the state transition matrix p, $U_i = U \times P$.
The following results are obtained when the patient chooses PD.

$$\begin{aligned}
p_1 &= [0.0020.0050.120.220.450.201]\,,\\
p_2 &= [0.0340.410.410.16]\,,\\
p_3 &= [0.0010.070.560.270.119]\,,\\
p_4 &= [0.0050.0290.3320.310.210.234]\,,\\
p_5 &= [0.0580.450.370.110.082]\,,\\
p_6 &= [0.0030.310.390.060.237]\,.
\end{aligned}$$

When he chooses HD, the corresponding results are:

$$\begin{aligned}
p_1 &= [0.0020.0070.1200.2200.4100.21]\,,\\
p_2 &= [0.0160.2900.2900.360]\,,\\
p_3 &= [0.0010.0500.3600.2700.219]\,,\\
p_4 &= [0.0020.0090.1720.1510.1300.034]\,,\\
p_5 &= [0.0280.3500.4100.2800.082]\,,\\
p_6 &= [0.0050.3000.4100.0600.237]\,,\\
C_{PD} &\approx 70000,\\
C_{HD} &\approx 80000.
\end{aligned}$$

Table 56.4 Cost-Effectiveness analysis of PD treatment of ESRD

Scheme	Cost (RMB)	Initial health utility (U)	Posttreatment health utility (U_1)	Health utility increment (ΔU)	Cost-effect analysis (CBA)	Adaptive choice
PD	70,000	0.551	0.641	0.09	77.78	Recommended decision

Table 56.5 Cost-Effectiveness analysis of HD treatment of ESRD

Scheme	Cost (RMB)	Initial health utility (U)	Posttreatment health utility (U_1)	Health utility increment (ΔU)	Cost-effect analysis (CBA)	Adaptive choice
HD	80,000	0.551	0.647	0.096	83.34	Not recommended decision

56.4.4 Results

See Tables 56.4 and 56.5.

56.5 Results

56.5.1 Establishing a Markov Model

(1) Parameters

① Cost Parameters

Costs of ESRD dialysis treatment are divided into the dialysate costs, hospital costs, and so forth. The total annual costs of peritoneal dialysis and hemodialysis are 70, 000 yuan per year and 80, 000 (The total annual costs of peritoneal dialysis and hemodialysis are rough estimates based on the past treatment costs, for the cost calculation is not the focus of this paper.) per year, respectively.

② Health Utility Values

The calculation method of health utility values can be found in Sect. 56.2.3.

(2) State Transition Probability

According to the method mentioned in Sect. 56.2.4, the paper finds the state transition rules of patients who receive the two dialysis treatments. Then, it predicts the state transition probabilities of patients with different treatments. After estimating the transition probabilities of each state of a patient, the patient's state transition matrix can be established (see Sect. 56.4.3).

(3) Calculation Method

Taking PF (Physical Function) for example, the pre-treatment value of PF multiplied by p1 (the corresponding state transition probability) equals the post-treatment value of PF. By the same token, this approach applies to the other five dimensions. Then, using Eq. (56.2), the paper calculates the health utility value of patients who receive a treatment. After that, the cost-effectiveness analysis is conducted.

(4) Results of Treatment

The paper uses the Markov model to simulate kidney disease treatment process of Mr. Xu, and then compares the cost-effectiveness of different treatments (PD and HD). Eventually, a conclusion is reached that PD is more suitable for Xu.

56.6 Conclusion

First, both of the two treatments relieve patients' pain, improving their family life and social life significantly. Compared to HD, PD patients have fewer psychological problems, but at the same time they are less energetic. Given the advantages of PD and limited medical resources in China, the government should actively promote the popularization of peritoneal dialysis (PD). In this way, the government assists patients who cannot receive treatments in hospitals due to their economic conditions. Moreover, the promotion of peritoneal dialysis treatment has economic benefits, and it will enhance medical resource utilization.

Second, in terms of a real patient Mr. Xu, the paper quantifies his pre-treatment quality of life, estimates his state transition matrix, and predicts his post-treatment value of health-related quality of life (HRQoL). Then, it proceeds to conduct a cost C effectiveness analysis. Ultimately, the paper concludes that if Xu chooses PD, he will obtain greater economic and clinical benefits.

Acknowledgments The work is supported by the National Natural Science Foundation of China (Grant No. 71301109), the Western and Frontier Region Project of Humanity and Social Sciences Research, Ministry of Education of China (Grant No. 13XJC630018), the Philosophy and Social Sciences Planning Project of Sichuan province (Grant No. SC12BJ05), and the Initial Funding for Young Teachers of Sichuan University (Grant No. 2013SCU11014).

References

1. Fenton SS, Schaubel DE et al (1997) Hemodialysis versus peritoneal dialysis: a comparison of adjusted mortality rates. Am J Kidney Dis 30(3):334–342
2. Hays RD, Kallich JD et al (1994) Development of the kidney disease quality of life (KDQOLTM) instrument. Qual Life Res 3(5):329–338
3. Huang RF, Zhou QL (2009) The clinical decision-making of kidney replacement therapy ways on patients with end stage renal disease. Med Philos 6:52–54 (in Chinese)

4. Lowney AC, Myles HT et al (2015) Understanding what influences the health-related quality of life of hemodialysis patients: a collaborative study in england and ireland. J Pain Symptom Manag 50(6):778–785
5. Wu HX (2012) A study on measurement of health utility value (in Chinese)
6. Xiao Y, Sui BY, Zhao K (2011) Epidemiological features of the end-stage renal disease and the application, cost and payment of dialysis care in china. China National Health Development Research Center 4
7. Yang F, Griva K et al (2015) Health-related quality of life of asian patients with end-stage renal disease (ESRD) in Singapore. Qual Life Res 24(9):2163–2171

Chapter 57
Founder Personalities' Influence on Decision Making of VC Institution: An Empirical Study in China

Yingkai Tang, Wenjun Wang, Yanru Chen and Huang Huang

Abstract Venture capital (VC) makes great contribution to start-up companies. It is essential to support VC in order to realize adjustment and transformation of economic structure. Venture capital institutions (VCI) invest the company for benefit. So it is important to study their preference for invested companies. Founders are always the soul of a company. This paper studies VCI preference for specific founder personality based on data of GEM companies. By doing empirical study, descriptive statistics, correlation analysis and logistics regression analysis, specific founder personalities were sort out. The conclusion is that abroad studying or working experience and political background of the founder are positively related with VCI's investment decision.

Keywords Venture capital · Founder personality · Investment decision

57.1 Background

Venture capital, the so called VC, makes great contributions to economy since it came into being. Cheng [2] proposed the three functions of VC for economy, which are engineering and commercialization of research result, promoting the development of high-tech and offering effective investment. The transformation from ideas to industries is realized through four stages, which are research, develop, experiment and marketing. The first two stages are featured with high risk, long time and more capital. The founder has no capital but technology at the early stage, while banks and common investors are not willing to offer capital. On the contrast, VC can provide both capital and governance guidance to help the company.

VC is of significant importance for adjustment and transformation of a country's economy, especially China. In China, 99 % of the companies are of small and medium

Y. Tang · W. Wang · Y. Chen · H. Huang (✉)
Interenational Business School, Zhongshan University, Guangzhou 510275, Guangdong, People's Republic of China
e-mail: huanghuanglydia@outlook.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_57

size. They provide 80 % jobs, while their chance of keeping alive is only 2 %. VC is also important for the rejuvenation of China. In the 2014 government report, Premier Keqiang Li said that we need to support companies in growth enterprise market (GEM) to build a better multi-level capital market. It is obvious that the Chinese government had paid great attention to VC. And VC is bound to have a bright future. It goes without saying that VC is very important. But there exists problems. How to gain VC? And what's VCI preference for project? Solving these problems is meaningful for both the company and the government.

57.2 Literature

As early as in 1960, Myers and Marquis [1] put forward the MM theory. They did empirical study; but ignored many non-financial indexes, such as market potential, technical prospect and founder personality. The following papers all talked about this issue. Tyebjee and Brono [4] summarized the five factors influencing VCI's investment decision by doing questioners for 90 projects invested by 41 VCI in American. The five factors are market attractiveness, management ability, product differentiation, resisting ability for environment threat and retreat channels. The projects were scored in two perspectives, return rate and risk. Timmons [3] designed a model to choose VC projects, which included eight indexes, industry and market, economy, profiting condition, advantages, management team, fatal defects and differences between founders' ideal personalities and practical personalities. Among the eight factors, two of them are related with founders' personality and experience.

Domestic studies about the factors influencing investment decision are mostly modified versions of the abroad studies according to the practical situation in China. Chen [6], a researcher in Taiwan, built a VCI assessment system based on VCI development in Taiwan. The system had five parts, which are competitiveness of the project, internal competitiveness of the company, external opportunities and threats, operation target and risk management. Internal competitiveness of the company includes personalities and management ability of the founder. He and Li [7] studied founder personality's contribution to company development based on 277 questionnaires. The study was done in four perspectives, which were strategic ability, management ability, government relation and social relationship. Wu and Liu [8] studied the relation between founder's political background and enterprise value based on the 1046 private companies listed in Shanghai and Shenzhen Exchange. Their conclusion was that location and level of the political background influence its potency. Zhou, Guo and Wang [9] did a study by using quasi-experiment. The experiment's focus was on social network of both the company and the founder themselves.

57.3 Research Design

57.3.1 Data Sources

The data in this paper come from the prospectus of GEM companies listed in 2009, 2012, and 2014. We analyze VCI preference when making investment decisions, and reach the conclusion that founder's personality has influence on VCI investment decision.

57.3.2 Variable and Definitions

Independent variable: We searched the prospectus to see if the company was joined by VC. If so, the variable equals to 1; 0 otherwise.

Table 57.1 Table of variables

Dependent variable	Joined with VC or not; VC	If one of the top ten share holders is VC, the variable equals to 1, 0 otherwise
Independent Variable	Gender of the founder; Gen	If the founder is male, the variable equals to 1,0 otherwise
	Age of the founder; Age	Age of the founder, the variable has four values, which are 0, 1, 2, 3 and 4; and corresponding with the ages below 30, ages between 30 and 45, ages between 45 and 60 and older than 60
	Education level of the founder; Edu	Education background of the founder, this variable has four values, which are 0, 1, 2, 3 and 4, and corresponding with below bachelor, bachelor, master and doctor or over
	Having abroad experience or not; Out	Abroad experience of the founder, if the founder has abroad experience, the variable equals to 1, 0 otherwise
	Having similar working experience or not; Exp	Similar working experience of the founder, if the founder has similar working experience, the variable equals to 1, 0 otherwise
	Having political background or not; Pol	Political background of the founder, if the founder was once member of the congress or CPPCC, top manager of state-owned company, or employee of large research institutions, the variable equals to 1, 0 otherwise
Controlling variable	Industry of the company; Ind	The 10 industries are agriculture, forestry and fishing, manufacturing, water and electricity gas, construction, wholesale and retail, transportation, warehousing, information technology, scientific research and service, health, public environmental and cultural transmission, which corresponding with the value of 1 to 10
	Location of the company; Loc	The 7 locations are the northeast, north, east, south, central, northwest, southwest, which corresponding with value of 1 to 7

Independent variable: There are 6 independent variables in total. First is the sexuality of the founder. Variable of male founders equals to 1, 0 otherwise. The second is age. The variable has four values, which are 0, 1, 2, 3 and 4; and corresponding with the ages below 30, ages between 30 and 45, ages between 45 and 60 and older than 60. The third is education background. This variable also has four values, which are 0, 1, 2, 3 and 4, and corresponding with below bachelor, bachelor, master and doctor or over. The fourth is abroad experience. If the founder has abroad experience, the variable equals to 1, 0 otherwise. The fifth is similar working experience. If the founder has similar working experience, the variable equals to 1, 0 otherwise. The last one is political position of the founder. If the founder was once member of the congress or CPPCC, top manager of state-owned company, or employee of large research institutions, the variable equals to 1, 0 otherwise.

Controlling variable: Controlling variables are industry and location of the company. There are mainly 10 kinds of industries, which corresponding with the value of 1 to 10. There are mainly 7 kinds of locations, which corresponding with the value of 1 to 7 (Table 57.1).

57.4 Analysis of the Result

57.4.1 Descriptive Statistics

According to the result, companies joined with VC mainly locate in the north, east, and south. In 2009, when the GEM just started, most of the VC projects are in the east, which takes 1/3; that of the north takes 1/4; and that of the northeast takes 2.8 %, which is the least. Projects in the south, central and southeast have the same number, which equals to 11.1 % respectively. Three years are GEM started, the east area still has the most VC projects, which takes nearly half of the total. The north and the south ranked the second, which takes 20 % respectively. Projects in the northwest, southwest and northeast are still very little, which totals 5.5 %. In 2014, when the GEM was stopped, areas that have the most VC projects are still the east and the north, with north having the most, which takes about 40 %. VC projects in the northwest and northeast increase to 5.6 %, while that of the southeast has no changes.

According to the statistics of industry, GEM companies of manufacturing are invested the most, which takes more than 60 %. That of information technology takes around 20 %. That of scientific research and cultural transmission takes only 3 %. Some industries differentiate the most compared with the others, for instance, VC invest to agriculture, forestry and fishing, water and electricity gas and construction only in 2012. VC invest to wholesale and retail only in 2009 and takes very small percent. In 2014, great differences came into being, for instance, VC invest more to newly born industries like public environment protection instead of the traditional industries. This is inconsistent with the economy development in China; and reflects the adjustment and revolution of economy in some degree.

According to the statistics of independent variable, the number of companies joined with VC is obviously more than that of those without. The percentage of the latter of the total keeps decreasing.

Seen from Table 57.2, we can see that male founders take more than 90 % on average, and reach to 97 % in 2009. In terms of the age, the number of founders aged between 45 and 60 is the largest; that between 30 and 45 ranked the second; that of over 60 takes only 10 %. No founder's age is under 30. In terms of the education background, the number of founders owning master degree is the largest; that owning bachelor degree and doctor degree or higher ranked the second and the third. The number of founders with bachelor degree or below is the least.

In addition to the above, education background of the founder differentiate in different years. In 2009, founders owning doctor degree or above takes about 27.8 %, which is far more than founders owning bachelor degree, which takes only 19.4 %. Founders owning degree below bachelor takes 5.6 %, which is the least. In 2012, the number of founders owning master degree still takes the most percent. But the percent of founders owning doctor degree or above decreased to 5.4 %, which is the lowest since 2009. The number of founders owning bachelor degree or below increased to more than 20 %; and it is the same in 2014.

Thus, education background of the founder is not the main factor. This reflects that founders pay more attention to other perspectives other than their education background. In terms of abroad experience, more than 80 % of the founders had no abroad studying or working experience. But 95 % of the founders had working experience similar with the enterprise they built . The majority of the founders had no political background. But 40 % of them were once member of the congress or CPPCC or top manager of state-owned company.

57.4.2 Correlation Analysis

Seen from Table 57.3, dependent variable is positively related with variable Out and Loc under 5 % level. Variable Gen is not related with any others in this paper, which means that VCI didn't have the traditional idea of patriarchal society when choosing VC project. Variable Out and Exp are positively related with Edu under 5 % level. This is consistence with the social cognition. People with higher education background have more chances to study or work abroad. Variable Exp is not related with any other variable. This can be explained in that founders in this paper all have similar working experience. So variable Exp is like a constant and has no obvious relation with other variables. Variable Pol and Age are positively related with variable Ind under 5 and 1 % level respectively. Generally speaking, founders with older age have more human networks and professional knowledge and more remarkable political background. Thus their companies develop faster and can gain more chances of being invested by VCI.

Table 57.2 Statistics of the independent variable

		2009		2012		2014	
		Frequency	Percent	Frequency	Percent	Frequency	Percent
Gender	Female	1	2.8	6	8.1	4	7.4
	Male	35	97.2	68	91.9	50	92.6
Age	30–45	17	47.2	20	27	12	22.2
	45–60	16	44.4	46	62.2	36	66.7
	60 or above	3	8.3	8	10.8	6	11.1
Education level	Bachelor or below	2	5.6	16	21.6	11	20.4
	Bachelor	7	19.4	23	31.1	18	33.3
	Master	17	47.2	31	41.9	22	40.7
	Doctor or above	10	27.8	4	5.4	3	5.6
Abroad experience	Yes	31	86.1	63	85.1	45	83.3
	No	5	13.9	11	14.9	9	16.7
Similar working experience	No	2	5.6	0	0	0	0
	Yes	34	94.4	74	100	54	100
Political background	No	22	61.1	65	87.8	33	61.1
	Yes	14	38.9	9	12.2	21	38.9

Table 57.3 Correlation

		VC	Gen	Out	Exp	Pol	Edu	Age	Loc	Ind
Joined with VC or not	Pearson correlation	1	−0.127	0.157*	0.091	0.109	0.092	−0.076	−0.175*	0.015
	Significance (both side)		0.105	0.045	0.246	0.167	0.241	0.338	0.025	0.849
	N	164	164	164	164	164	164	163	164	164

*Significant under 0.05 level
**Significant under 0.01 level

57.4.3 Multiple Regression Analysis

The dependent variable in this paper is dummy variable. We used logistic model to analyze the factors influencing VCI's investment decision making in turn.

The first model analyzes basic factors, which are gender and age. The result shows that these two factors failed the significance test. The reason for this may be that most founders of the listed companies are male. So the variable Gen become a constant; or that VCI does not take the gender of the founder into consideration when making decisions. The majority of the founders are around 45 years old. This may result from the high threshold of listed companies and cumbersome approval process. Besides, only founders who are around 45 may own all the resources to make the company public. So age of the founder has little or none influence on decision making for VCI.

The second model brings in the variable Edu. The result shows that the variable fails the significance test, which means education background of the founder has no influence on decision making. One possible reason is that high education is not worshiped blindly in these days. VCI consider more of the founder's ability instead of the education background, which is consistence with the standard for choosing talents in China. Contrary to the above, variable Out passes the significance test, which means that founders with abroad studying or working experience has more chances of gaining the investment. There are two possible reasons. The first is that abroad experience broadens the founders' vision and gives them more opportunities to engage the advanced technology. The second is that this kind of founder can easily gain foreign resources compared with others.

The third model brings in the factor of social resource. The result shows that variable Exp is not significant, while variable Pol passes the test. This may be explained by the regional character of political background. VCI is more willing to choose the founders with political background who have more chances of gaining benefit because of the specific advantage.

57.5 Conclusion

This paper takes the companies listed in three specific point of time as samples and collected data of founder's personality from prospectus. We draw several conclusions by doing comparative analysis, statistical analysis, difference analysis, correlation analysis and multiple regression analysis. The conclusions are as follows:

Variable Gen and Age have no significant influence on decision making for VCI. This reflects that VCI chooses projects based on reasonable judgments. They neither think superior of male founders nor think inferior of female founders. Besides, it shows that most founders are between 45 and 60 years old. Young entrepreneurs are less likely to make the company public, which may result from the lack of experience and high threshold. Education background of the founders has no significant influence on decision making for VCI. This means that VCI evaluate the founders based on many other perspectives beside the education background. It is a reflection of improvement and rationalization toward assessment standard.

Abroad experience of the founder has significant influence on decision making for VCI. This reflects the requirement of cooperation with multinational economy in China. VCI thinks highly of the founders who know about foreign culture.

This means that founders with political background have more ways to get information and can get political protection easier, so their company has more chances of being invested.

For the limitation of collecting data, all the data in this paper come from the prospectus and the internet. It is possible that information in the prospectus is faked up; and those searched on the internet is not always true.

At the very first of our study, we also took founder's personal charisma and attitude towards life into consideration, whereas, it is a pity that we can't collect the related information and are forced to abandon this variable finally. We intend to find more ways to collect timely and accurate data and refine the research in the future.

Acknowledgments This research was founded by National Science Foundation of China (71072066, 71302183) and Sichuan University (2013JCPT006, SKGT200602).

References

1. BarNir A (2012) Starting technologically innovative ventures: reasons, human capital, and gender. Manag Decision 50(3):399–419
2. Bygrave WD, Timmons J et al (1999) Venture capital: predictions and outcomes. Venture capital at the crossroads and realizing investment value revisited. Chapter
3. Chen Z (1986) Investment decisions of our current venture capital institutions. National Taiwan University, Institute of Business Studies Master's thesis
4. Cheng S (1999) Develop venture capital of China actively yet steadily. Manag World 50(3):2–7
5. Deventer V, Gert A (2008) Factors influencing venture capitalistsproject financing decisions in South Africa. Ph.D. thesis, University of Stellenbosch
6. He X, Li X (2005) Entrepreneurial competence and enterprises' growth: an empirical study in China. Econ Res J 10:101–111
7. Li H, Zhang Y (2007) The role of managers' political networking and functional experience in new venture performance: evidence from China's transition economy. Strateg Manag J 28(8):791–804
8. Luehrman TA (1998) Investment opportunities as real options: getting started on the numbers. Harv Bus Rev 76:51–66
9. Myers SC, Majluf NS (1984) Corporate financing and investment decisions when firms have information that investors do not have. J Financ Econ 13(2):187–221
10. Ozmel U, Reuer JJ, Gulati R (2013) Signals across multiple networks: how venture capital and alliance networks affect interorganizational collaboration. Acad Manag J 56(3):852–866
11. Ozmel U, Robinson DT, Stuart TE (2013) Strategic alliances, venture capital, and exit decisions in early stage high-tech firms. J Financ Econ 107(3):655–670
12. Tyebjee TT, Bruno AV (1984) A model of venture capitalist investment activity. Manag Sci 30(9):1051–1066
13. Wu W, Wu C, Liu X (2008) Political connection and market valuation: evidence from China individual-controlled listed firms. Econ Res J 7:130–141
14. Zhou L, Guo R, Wang N (2014) What are the trait factors which influence the decision of VC investment. China Soft Sci 11:105–114

Chapter 58
A Stochastic Bilevel Programming Model for the Iron and Steel Production Optimization Problem Under Carbon Trading Mechanism

Zhimiao Tao

Abstract In this paper, we focus on the optimal production problem for iron and steel problem under the carbon emission trading mechanism. A bilvel programming model with stochastic factor is developed, in which the leader and follower are the authority and the plant, respectively. Some results are derived from a case study. Finally, policy suggestions are proposed to the help improve the decision-making process of the plant and authority simultaneously.

Keywords Stochastic bilevel programming model · Iron and steel production · Intelligence algorithm · Carbon trading mechanism

58.1 Introduction

Warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia [8]. Global warming is not only a significant environmental challenge, but also an important issue that deeply affects the world's political-economic pattern, and human production and life style. Anthropogenic greenhouse gas (GHG) emissions are the main cause of climate change. Among the six kinds of GHG covered under the Kyoto Protocol, emissions of Carbon dioxide (CO_2) from fossil fuel combustion and industrial processes contributed about 78 % of the total GHG emissions increase from 1970 to 2010, with a similar percentage contribution for the increase during the period 2000–2010 [8]. Many measures are adopted to reduce CO_2-emissions. Many measures are adopted to achieve the CO_2-emissions reduction goal. Some of them are based on technological aspects, such as the usage of the renewable energies, energy saving technologies, and carbon capture and storage (CCS) [4]. In addition to technological means, managerial and economic approaches are also designed to meet emissions mitigation standards.

Z. Tao (✉)
Low Carbon Technology and Economy Research Center, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: taozhimiao@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_58

In Kyoto Protocol, the landmark of human's efforts in response to the global climate change, emissions trading (ET), clean development mechanism (CDM), and joint implementation (JI) were presented, realize CO_2 reduction in a cost-effective way. Among them, ET mechanism, a market-based instrument, is regarded as the most cost-effective way to meet the CO_2-emission limits [12]. In practice, some ET markets are in operation, e.g. the European Union Emissions Trading System (EU ETS). Perdan and Perdan [10] do a summary for current emissions trading schemes.

Iron and steel is a kind of main structural material and the functional material with highest production for the human society. Iron and steel industry is associated with many other industries (e.g., transportation industry, petrochemical industry, construction industry), playing an irreplaceable role in modern economic lives. After construction and development for more than one hundred years, the iron and steel industry has formed a large industrial system involving geological prospecting, sintering, coking, ironmaking, steelmaking, steel rolling, etc. By 2014, the crude steel production exceeded 1. 66 billion tons (See Fig. 58.1). With the rise of some emerging market countries, particularly China, the demand for steel will continue to grow in a fairly long period of time. Iron and steel industry is both main carbon source and technology-intensive industry, thus it has strong potential to reduce emissions.

Researchers applied different methodologies to analyzed CO_2 abatement of the iron and steel industry in specific countries or international comparison. These methodologies include engineering perspectives and economic approaches. Tanaka [11] used two methods to calculate CO_2 emission, the European Union Emission Trading Scheme and a method developed by the Japanese Iron and Steel Federation, to investigate the effect of the accounting method on the assessment of energy saving by four model steel mills with different levels of energy efficiency. Gielen and Moriguchi [5] developed a linear programming model for the analysis of CO_2 emission reduction potentials in the Japanese iron and steel industry. This model can be used to analyse the impact of CO_2 taxes on technology selection, iron and steel trade and product demand for the next three decades. Xu and Cang [1] made an overview of new CO_2 breakthrough technologies for iron and steel making. Hidalgo et al. [7] developed a world simulation model able to analyze the evolution of the

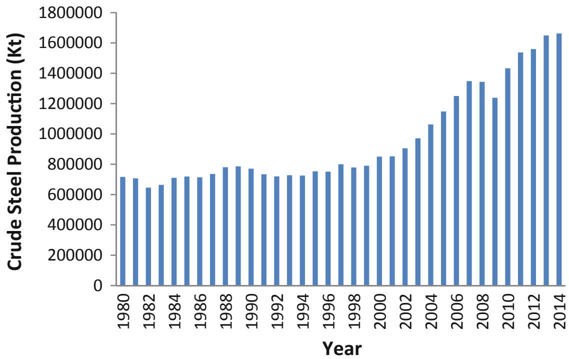


Fig. 58.1 World crude steel production 1980–2014. *Source* World Steel Association

industry from 1997 to 2030, focusing on steel production, demand, trade, energy consumption, CO_2 emissions, technology dynamics, and retrofitting options.

The above studies provide some viewpoints on the CO_2 emissions for the iron and steel industry from different aspects. However, the best of our knowledge, there is little work of using mathematical programming model to describe the this kind of emissions problem. In fact, accurate mathematical programming model and relevant solution methods can help decision makers improve the decision-making quality. In this paper, we develop a bilevel programming model for the iron and steel production optimization problem under carbon trading mechanism and provide some constructive suggestions to the decision subjects.

The remainder of this paper is organized as follows. Sections 58.2 and 58.3 introduces the research methodologies. Section 58.4 analyzes the research results. Finally Sect. 58.5 presents the major conclusions and policy suggestions.

58.2 Problem Statement

When considering the optimal production problem of iron of steel plants under the carbon emission trading mechanism. There are two participants must be taken into consideration, the plant's decision maker and the authority. All the carbon emission trades initiates the allocation of CO_2 emission permits from the authority. The authority is responsible for making legislations of the emissions, supervising the trading market by the financial and policy tools and allocating the CO_2 emission permits. So the authority play the role of leader in the carbon emission trading scheme. Since the iron the steel industry is energy-incentive and carbon-intensive, the iron the steel plant's production is affected by authority's emission legislation significantly. The plant's decision maker should consider the issue of carbon emission before making production plans. In this sense, the iron the steel plant is the follower in the emission trading scheme. Hence it is suitable to use bilevel programming model [2] to describe the relationship of the authority and iron of steel plant.

With the increasingly strict environmental policy, the backward-technology plants eliminated from the fierce competition. The industrial concentration degree keeps rising. For example, during 2000∼2008, CR5 (industrial concentration of top 5 steel company) of Japanese steel industry gradually increased from 70 % to 80 % [9]. In 2011, the Ministry of Industry and Information Technology of China issued "the 12th Five-Year development plan of the iron and steel industry". It is possible that there is only one iron and steel plant in a region. This study focus on the case of involving one plant. The authority is responsible for making for allocating the free CO_2 emission quota and making the price strategy for paid quota to aim at optimizing total CO_2 emission as well as the revenue. There are some studies on pricing mechanisms [3, 6, 13]. With regard to the plant, it is essential to determine the system boundary for calculating the CO_2 emissions. This boundary is presented in the next section.

58.3 Modelling

In this section, a stochastic bilevel programming model for the iron and steel plant's production optimization problem under carbon trading scheme is developed.

58.3.1 Assumptions

First of all, some requisite assumptions are listed as follows:

(1) The authority allocate the initial quota to iron and steel plant only once. The plant considers a single period production problem. In other words, this is a static programming problem.
(2) The crude steel is the only product.
(3) The are three sources for the plant to obtain the needed emission quota: the authorities' allocation for free, the authorities' paid allowance and the emissions trading market with other company.
(4) The demand for the crude steel and the emission allowance in the trading market are stochastic.
(5) The iron an steel plant is the main CO_2 emission source in this region.

58.3.2 Notations

Q_0: the local authority's emission quota allocated by the central government constant;
Q_1: the quantity of free CO_2 emission allowance from the authorities, decision variable;
Q_2: the quantity of paid CO_2 emission allowance from the authorities, decision variable;
Q_3: the quantity of paid CO_2 emission allowance from the trading market; A positive Q_3 means the plant needs to purchasing allowance to satisfy its production while a negative Q_3 represents the plant sell the surplus allowance to the trading market;
C_2: unit price for the paid allowance, constant;
C_3: unit price for the emission allowance from the external market, a random variable;
C_u: unit loss of unmarketable crude steel, $C_u < p$;
T: tax levied from unit crude steel;
Q_s: the production quantity of crude steel, the decision variable of the plant;
Q_c: the maximal production capacity;
K: unit fixed cost for producing unit ton crude steel;

r: the market's demand (ton), which is a random variable, following from the distribution $\phi(r)$;
P: the expected value of price of per unit ton crude steel;
E: the total carbon emission.

58.3.3 Model Formulation

The problem involves the authorities and the plant. The authorities set the allocation strategy and the plant make its optimal production plan correspondingly. The details are descried as follows.

(1) The Model for the Local Authority

The authorities not only need control the cap of the CO_2 emission based on the environmental legislation but also raise the revenue to improve the infrastructure construction. So there are two objectives for the authorities. This first objective is to minimize the total CO_2 emission of this plant, which is presented as

$$\min F_1 = Q_1 + Q_2 + Q_3. \tag{58.1}$$

Since Q_1 and Q_2 are the leader's decision variables, (58.1) signifies that the authorities try to control the emission target by adjusting the ratio of free quota and paid quota.

In view of the financial situation, the authorities need to maximize the revenue to support municipal construction.

The authorities' revenue considered here is comprised of the sale of paid quota and levies on iron and steel products. The main items of taxation include value added tax and corporate income tax. This study assume that the unit output is levied single tax. Thus, the objective of maximizing the revenue is developed as:

$$\max F_2 = C_2 Q_2 + T Q_s. \tag{58.2}$$

If the local authority allocates all the emissions quota for free, the revenue may decrease due to the zero of $C_2 \times Q_2$. On the contrary, only focusing on the revenue leads to the plant willful emissions possibly. Thus, there exists some conflict between F_1 and F_2, the authority should use the price lever to make tradeoff between F_1 and F_2.

Since the local authority has a target on total amount control given by the central government, we have

$$Q_1 + Q_2 \leq Q_0, \tag{58.3}$$

Q_0 is the upper bound of allowance controlled by the local authority. The plant's own emissions above allowance will be severely punished.

(2) The Model for the Iron and Steel The Plant

In the situation of marketing economy, the only target of the plant is the pursuit of maximum profit. The profit of the plant in a production period equals its sales revenue minus different sorts of expenses.

This objective can be expressed as

$$\min f = \int_0^{Q_s} pr\phi(r)dr + \int_{Q_s}^{+\infty} pQ_s\phi(r)dr - KQ_s - \int_0^{Q_s} C_u(Q_s - r)\phi(r)dr \\ - C_2 \times Q_2 - T \times Q_s - C_3 \times Q_3. \tag{58.4}$$

In Eq. (58.4), different items have the following meanings.

- $\int_0^{Q_s} pr\phi(r)dr$, and $\int_{Q_s}^{+\infty} pQ_s\phi(r)dr$ are the sales revenues when supply exceeds demand and demand exceeds supply, respectively.
- $K \times Q_s$ is the the fixed production cost.
- $\int_0^{Q_s} C_u(Q_s - r)\phi(r)dr$ is the cost when the crude steel is unsalable. The cost may be the inventory cost or recovery cost.
- $C_2 \times Q_2 + T \times Q_s$, i.e., F_2, is the cost that pay to the authorities.
- $C_3 \times Q_3$ is the cost of purchasing emission from the trading market.

The production of crude steel cannot be infinite under any policy and market conditions due to the capacity constraint. The capacity mainly depends on the number of blast furnaces and their effective volume. The capacity constraint is presented by

$$Q_s \le Q_c. \tag{58.5}$$

As the emissions are concerned, the plant's emission should not exceed the available quota.

$$E \le Q_1 + Q_2 + Q_3. \tag{58.6}$$

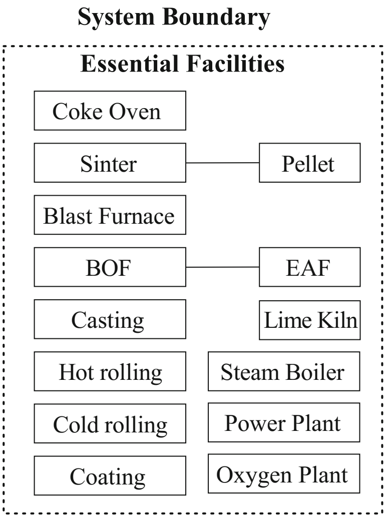
This value of E is the product of product quantity Q_s, the energy consumption intensity (ton per ton steel) and CO_2 emission intensity (t). Since a iron and steel plant involves various emission resources, it is essential to determine the system boundary. In this study, we adopt the system boundary proposed by world steel association (http://www.worldsteel.org) (see Fig. 58.2).

Real-time monitoring system for CO_2 emission measurement is not developed out of cost and technology. So we calculate the amount of CO_2 emission with the material balance. Emission are from fuel combustion, flux consumption ($CaCO_3$ et al.) in steel-making processes and electricity consumption, where fuel combustion and flux consumption direct emissions and electricity consumption is indirect emissions.

The emission from per unit steel is determined by the following equation:

$$E_{\text{fuel}} = \sum_i E_i \times \text{NCV}_i \times F_i^{\text{cov}} \times O_i, \tag{58.7}$$

Fig. 58.2 System boundary



where subscript i represents energy fuel type i; E_i is the energy consumption for production 1 t steel (in tons, t); NCV_i is the net calorific value of fuel (TJ/t or TJ/Nm^3); F_{cov} is a conversion factor factor [tCO$_2$/TJ]; O_i represents the oxidation rate of fuel type i. This product $NCV_i \times F_i^{\text{cov}}$ is also called emission factor of fuel type i (tCO$_2$/t).

In the process of iron and steel production, flux is used as basicity regulator in sinter, slag in steelmaking, steel furnace charge etc. The flux comprise limestone ($CaCO_3$), dolomite ($MgCO_3$) and magnesite ($CaMg(CO_3)_2$), which releases CO_2 during melt in the high temperature from the following chemical reaction equations:

$$\text{CaCO}_3 = \text{CaO} + \text{CO}_2,$$

$$\text{MgCO}_3 = \text{MgO} + \text{CO}_2,$$

$$\text{CaMg(CO}_3)_2 = \text{CaO} + \text{MgO} + 2\text{CO}_2.$$

Hence, the emission released from unit flux is

$$E_{\text{flux}} = \frac{44}{100} M_{\text{CaCO}_3} + \frac{44}{88} M_{\text{MgCO}_3} + \frac{88}{184} M_{\text{CaMg(CO}_3)_2}. \tag{58.8}$$

The carbon content of pig iron is higher than the content of steel, so steel-making is the process of carbon reduction. The CO_2 release in the process of carbon reduction of unit crude steel is calculated by the following equation:

$$E_p = (C_p - C_{cs}) \times \frac{44}{12}. \tag{58.9}$$

According to China's national bureau of statistics data (http://www.stats.gov.cn), the China's total crude steel output is 1.08 billion tons and electricity consumption 4976.26 billion kWh in 2013. The average electricity consumption is 465 kWh for 1 ton crude steel (http://www.chinaisa.org.cn). It is estimated that the electricity consumption related with iron and steel industry accounting for more than 10 % of the total electricity consumption. The electricity consumption is the most significant emission source. The emission related with electricity consumption is calculated by the following equation:

$$E_e = Q_e \times R_{ce} \times EF_{ce}, \tag{58.10}$$

where Q_e is the electricity consumption for 1 ton crude steel; R_{ce} coal equivalent (ce)-electricity conversion rate (tce/kWh); EF_{ce} denotes the emission factor of coal equivalent (tCO_2/tce).

Integrating Eqs. (58.7)–(58.10), the comprehensive emission intensity of 1 ton crude steel is $E_{\text{fuel}} + E_{\text{flux}} + E_p + E_e$. Thus, the total emission is the product of the output and comprehensive emission intensity, i.e.,

$$E = Q_s(E_{\text{fuel}} + E_{\text{flux}} + E_p + E_e). \tag{58.11}$$

Then the bilevel programming model for this problem is formulated by

$$\begin{cases} \min\limits_{Q_1,Q_2} F_1 = Q_1 + Q_2 + Q_3 \\ \max\limits_{Q_1,Q_2} F_2 = C_2Q_2 + TQ_s \\ \text{s.t. } Q_1 + Q_2 \leq Q_0 \\ \text{where } Q_s \text{ solves} \\ \begin{cases} \min\limits_{Q_s} f = \int_0^{Q_s} pr\phi(r)dr + \int_{Q_s}^{+\infty} pQ_s\phi(r)dr - KQ_s \\ \qquad - \int_0^{Q_s} C_u(Q_s - r)\phi(r)dr - C_2 \times Q_2 - T \times Q_s - C_3 \times Q_3 \\ \text{s.t. } \begin{cases} Q_s \leq Q_c \\ Q_s(E_{\text{fuel}} + E_{\text{flux}} + E_p + E_e) \leq Q_1 + Q_2 + Q_3. \end{cases} \end{cases} \end{cases} \tag{58.12}$$

58.4 Case Study

58.4.1 Data Collection

All the required data are collected from National Development and Reform Commission, China Steel and Iron Industry Yearbook, corporate annual reports and relevant technology standards.

The central government allocates the local authority's with 20,000 ton emission quota, i.e. $Q_0 = 20{,}000$. The authority sells the allowance with 20 yuan/ton, i.e., $C_2 = 20$. The tax levied from unit crude steel 1.5 yuan/ton, i.e., $T = 1.5$. The

Table 58.1 CO_2 emission factors for fuel used in calculations

	tCO_2/TJ
Coking coal,other bituminous coal	92.2
Coal for fuel	92.9
Coke oven coke	110.5
Blast furnace gas	100.3
Coke oven gas	41.3
Oxygen steel furnace gas	144.3
Coal tar, coal-based light oil	91.6
Heavy oil	77.1
Oil-based light oil	74.1
LPG	63.1
LNG, utility gas	56.0

Table 58.2 Energy conversion factors for fuel used in calculations

	Unit	MJ
Coking coal	kg	29.1
Coal for PCI (Pulverized Coal Injection)	kg	28.2
Other bituminous coal	kg	25.7
Coke ovencoke	kg	29.4
Coal tar	kg	37.3
Blast furnace gas	Nm^3	3.41
Coke oven gas	Nm^3	22.7
Oxygen steel furnace gas	Nm^3	8.41
Heavy oil	L	41.9
Kerosene	L	26.7
Light oil	L	37.7
LPG	kg	50.8
LNG	kg	54.6
Utility gas	Nm^3	44.8
Steam	kg	3.27
Electricity	kWh	8.81

maximal production capacity $Q_c = 1$ million ton per year. The unit fixed cost for producing unit ton crude steel $K = 150$ yuan/ton. The market's demand r follows normal distribution with mean 8 million tons and variance 1000. The expected value of price of per unit ton crude steel $p = 160$ yuan/ton. The CO_2 emission factors for fuel used in calculations are listed by Table 58.1.

The energy conversion factors used in this paper are based on the data used are shown in Table 58.2.

58.4.2 Results and Discussions

By using KKT conditions, we convert the bilevel model (58.12) into a single-level models. Some softwares for optimization, such as Matlab, can be used to obtain the solution. Based the data above, the optimal solutions are $Q_1^* = 16320$, $Q_2^* = 3680$, $Q_3^* = -1300$, $Q_s^* = 920000$. The optimal values for the authority and plant are $(F_1^*, F_2^*) = (18700, 1453600)$ and $f_1^* = 2868000$, respectively. $Q_1^* + Q_2^* = Q_0$ implies that plant will make full use of the emission allowance. $Q_s^* < Q_c$ means that plant runs under the capacity that may because the constraint of emission. In order to study the effects of the total quota Q_0 and unit emission price C_2, C_3, we change the values of them and solve the model for several times.

Fix the unit emission price, the solutions with different Q_0 are listed in Table 58.3. Table 58.3 implies the results as follows:

(1) All the allowances from the authority are used up, because the emission allowances is a kind of asset, both of the authority are willing to waste the allowance.
(2) As the Q_0 is low, i.e., the control level is relative strict, the plant needs to purchase the allowance from the external market. More precisely, $Q_0 = 18{,}700$ is a turning point. The plant purchases allowance to meet the production requirement if Q_0 is less than 18,700. Meanwhile, the plant sells the allowance to the market and obtain extra revenue.
(3) The value of Q_2 increases as Q_0 increase. Moreover, the proportion of Q_2 in Q_0 also increases. In other word, if the allowance control is relatively loose, the authority is willing to provide more allowance for free.
(4) More emission allowance brings better economic benefit. However, this results the increasing the actual emissions increase.

In what follows, we change the value of C_2 and fix other parameters. The results are listed in Table 58.4.

Table 58.4 implies the results as follows:

(1) The proportion of free allocation decreases as the unit price of paid allowance increase, which is because higher price make the authority tend to seek more revenue.

Table 58.3 Solutions with different Q_0

Q_0	$(Q_1^*, Q_2^*, Q_3^*, Q_s^*)$	(F_1^*, F_2^*, f^*)
10,000	(9,000, 1,000, 2,000, 600,000)	(12, 000, 975, 400, 1, 456, 000)
15,000	(13,500, 1,500, 1,000, 732,000)	(16, 000, 1, 273, 600, 1, 920, 000)
20,000	(16,320, 3,680, −1,300, 920,000)	(18, 700, 1, 453, 600, 2, 868, 000)
25,000	(18,000, 7,000, −2,300, 960,000)	(22, 700, 1, 617, 000, 3, 200, 000)
30,000	(19000, 11,000, −3,000, 1,020,000)	(27, 000, 2, 027, 000, 3, 368, 000)

Table 58.4 Solutions with different C_2

C_2	$(Q_1^*, Q_2^*, Q_3^*, Q_s^*)$	(F_1^*, F_2^*, f^*)
10	(19,500, 500, 2,200, 720,000)	(22, 200, 968, 400, 3, 667, 000)
15	(17,500, 2,500, 1,000, 732, 000)	(21, 000, 1, 289, 600, 3, 020, 000)
20	(16,320, 3,680, −1,300, 920,000)	(18, 700, 1, 453, 600, 2, 868, 000)
25	(16,000, 5,000, −2,500, 960,000)	(22, 500, 1, 717, 000, 2, 100, 000)
30	(15,000, 5,000, −3,200, 1,120,000)	(23, 200, 1, 827, 000, 1, 68, 000)

(2) The higher price of paid allowance benefits the authority's revenue to some extend and the actual emission. However, it will damage the palnt's interest. The plant have to pay more cost for emissions. Extremely high price of paid allowance may lead the plant stop production.And then it will damage the authority's interest. to avoid the cost.

For the parameters T, C_3, we also can study their effects on the decision makers's objectives' values.

58.5 Conclusions and Policy Suggestions

Considering a special case, i.e., a iron and steel plant is the main emission resource, we build a bilevel programming model, in which the authority is the leader and the plant is the follower. Taking into account the discussions above, several important conclusions are drawn as follows:

(1) The factor of the amount of emission quota that belongs to the authority and price affect the participants's behavior under the emission trading mechanism. High amount of emission quota and low price promote the economic development but will result in an increase in emissions. Economic development and emission control are conflict with each other.
(2) The authority and the plant are in a competitive situation. The authority has more priority. In order to achieve its goals (emission control, revenue), the authority tend to violate to the interests of the enterprise.

Based on the conclusions above and the actual situation of Chinese carbon emission trading market and enterprises' carbon emission reduction, we also put forward some important policy suggestions as follows:

(1) In the emission trading scheme, the authority has more priory. So when the authority tend to control the emission, it has to consider the economic development. Specifically, the authority should allocate more free allowance and reduce the price factor when the plant's competitiveness is weak to protect the economic development. On the contrary, the authority should allocate less free allowance

and increase the price factor when the plant has strong competitiveness to curb emissions.

(2) For the plant, when the authority allocates more free allowance and decreases the price factor, it should make full use of its production capability. On the contrary, when the authority allocates less free allowance and increases the price factor, it should make reduce its production accordingly.

Acknowledgments This research was supported by the Programs of NSFC (Grant No. 71401114), the Fundamental Research Funds for the Central Universities (Grant No. skqy201524).

References

1. Chunbao Charles X, Dq Cang (2010) A brief overview of low CO_2 emission technologies for iron and steel making. J Iron Steel Res, Int 17(3):1–7
2. Dempe S (2002) Foundations of bilevel programming. Springer Science & Business Media, Dordrecht
3. Feng ZH, Zou LL, Wei YM (2011) Carbon price volatility: evidence from EU ETS. Appl Energy 88(3):590–598
4. Gibbins J, Chalmers H (2008) Carbon capture and storage. Energy Policy 36(12):4317–4322
5. Gielen D, Moriguchi Y (2002) CO_2 in the iron and steel industry: an analysis of Japanese emission reduction potentials. Energy Policy 30(10):849–863
6. Hammoudeh S, Nguyen DK, Sousa RM (2014) Energy prices and CO_2 emission allowance prices: a quantile regression approach. Energy Policy 70:201–206
7. Hidalgo I, Szabo L et al (2005) Technological prospects and CO_2 emission trading analyses in the iron and steel industry: a global model. Energy 30(5):583–610
8. IPCC (2014) Climate change 2014: Synthesis report
9. Lin B, Wu Y, Zhang L (2011) Estimates of the potential for energy conservation in the Chinese steel industry. Energy Policy 39(6):3680–3689
10. Perdan S, Azapagic A (2011) Carbon trading: current schemes and future developments. Energy Policy 39(10):6040–6054
11. Tanaka K (2012) A comparison study of EU and Japan methods to assess CO_2 emission reduction and energy saving in the iron and steel industry. Energy Policy 51:578–585
12. Vine E, Kats G, Sathaye J, Joshi H (2003) International greenhouse gas trading programs: a discussion of measurement and accounting issues. Energy Policy 31(3):211–224
13. Zhu B, Wang P, Chevallier J, Wei Y (2014) Carbon price analysis using empirical mode decomposition. Comput Econ 2:1–12

Chapter 59
Gold Price Forecasting and Related Influence Factors Analysis Based on Random Forest

Dan Liu and Zhi Li

Abstract Gold price fluctuation trend prediction is an important issue in the financial world. Even small improvements in predictive performance can make lots of profits. In order to improve the prediction, various factors were considered in related literatures, such as US dollar index (USDX), the crude oil price (COP), Dow Jones Industrial Average (DJIA), the CPI of US (USCPI), the prices of US ten year bond futures (US10BFP), the Hang Seng Index (HIS) and the Standard & Poor's 500 Index (S&P500), etc. However, the more factors should be considered, the more difficult data can be gathered. This paper used the random forest method to predict the trend of fluctuations of the gold price. Our predictions are one month ahead. Extensive experiments based on real world data were conducted. Our findings show that (1) the random forest is a powerful method to predict the trends of fluctuations of the gold price and (2) the results also validated that, by using the random forest algorithm, there were only two factors must be considered to ensure the performance of the prediction, which were DJIA and S&P500.

Keywords Data mining · Machine learning · Gold price · Prediction · Influence factors

59.1 Introduction

Historically, the hedging function and ample liquidity of gold have attracted a large number of investors. Even when the financial crisis swept across the whole world, gold price remained at a high point. In fact, its distinctive characteristics make it an attractive investment vehicle: it acts as a store of wealth, a medium of exchange and a unit of value [8]. As far as risk is concerned, all of the financial markets have risks, gold market is no exception. The current gold market has the characteristic

D. Liu · Z. Li (✉)
Business School, Sichuan University, Chengdu
610065, Sichuan, People's Republic of China
e-mail: zhil1090@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_59

of high risk and profit existing side by side. Gold price fluctuate with the change of some influence factors, so the deep study on it is of benefit to grasp its nature and regulation accurately and improve the investment yield.

The causes of gold price fluctuations are very complex and the trend of gold price is influenced by many factors. Due to the gold price fluctuations are related with macroeconomic indicators closely, US dollar index (USDX), the crude oil price, Dow Jones Industrial Average (DJIA), the CPI of US, the prices of US ten year bond futures, the Hang Seng Index and the Standard & Poor's 500 Index (S&P500) are selected as the influence factors. These international macroeconomic indicators have the following effects on gold price:

(1) The impact of US Dollar Index (USDX)

Internationally, gold has been priced in dollars. If the dollar exchange rate increased, the gold price will decrease [11]. On the other hand, USDX has also affect the flow of funds between financial assets to affect the gold price. Generally speaking, when USDX increased, funds invested in US dollar assets will increase dramatically so that gold market will be relatively depressed and gold price will decrease [18].

(2) The impact of the Crude Oil Price

Oil price fluctuations affect the world economy especially the American economy. And the American economic trends affect the quality of the assets of the United States. Historically, there is a non-deterministic digital proportional positive correlation between gold price and oil price [7, 13].

(3) The Impact of Dow Jones Industrial Average (DJIA)

DJIA is the most influential and the most widely used stock index in the world. As the bellwether of the global economy, the impact of DJIA on gold price is obviously. Because of the function of risk hedging, gold investment can effectively offset the loss of stock investment. The Dow Jones index and gold price have a high negative correlation [15].

(4) The impact of the CPI of US

CPI is one of the important indicators when observing the inflation. In the long term, the CPI of US and the gold price is positive correlation [9]. Because gold has the function of resisting inflation [14], in the period of high inflation, gold will be favored by investors. So when the CPI increase, the gold price will increase.

(5) The impact of the prices of US ten year bond futures

The US Treasury market is the world's biggest bond market. Both the Treasury relying on the government credit and gold are high stability investments. Gold price is of positive relevance with the price of US ten year bond futures.

(6) The impact of the Hang Seng Index

The stock market and gold market are two of the most important in the portfolio choose market. Look upward from the cash flow, stock market and gold market usually are competitive [12].

(7) The impact of the Standard & Poor's 500 Index (S&P500)

The Standard & Poor's 500 Index is a market free float value-weighted index of 500 large publicity held companies, whose stocks are traded on the New York Stock Exchange, American Stock Exchange and the Nasdaq National Market System. The research result of Korhan K et al. displays a strong negative correlation between changes in the gold price and changes in S&P500 market price index [7].

Traditionally, the literature on forecasting gold price is not as various as it is in analyzing gold price movement and volatility, and the methods of forecasting are limited either. The research on the influence factors of gold price are mostly utilized multiple linear regression model and panel data model and other statistical methods. However, the statistical methods usually require the linear correlation between historical data. This request is not realistic. Some researchers have studied gold price fluctuations by applying flexible forecasting approaches that account for model uncertainty and model instability [1, 3]. With the rapid development of artificial intelligence and data mining technology, many new methods have been provided for modeling and forecasting of financial market. There are a number of different price modeling methods that have been discussed in literatures. Ballings et al. [2] benchmarked ensemble methods (Random Forest, AdaBoost and Kernel Factory) against single classifier models (Neural Networks, Logistic Regression, Support Vector Machines and K-Nearest Neighbor) for stock price direction prediction. Tsibouris and Zeidenberg [16] applied two models, a BP model and a temporal difference model, to six stock returns to test the weak form of Efficient Market Hypothesis (EMH). Chen and Shih [6] applied Support-Vector Machines (SVMs) and Back Propagation (BP) neural networks in forecasting six Asian stock markets. Li [10] used WNN model for gold price forecasting based on improved artificial bee colony algorithm. Zhang and Liao [17] found a method to forecast gold price based on RBF neural network and hybrid fuzzy clustering algorithm. Sonia [4] forecasted volatility in gold returns under the GARCH, IGARCH and FIGARCH frameworks. As only focusing on binary classification, these method only provided seldom information about trend of fluctuations of the gold price.

In this paper, random forest combination classification algorithm was used to predict the trend of fluctuations of the gold price, which improved the accuracy of the prediction significantly. Different from the previous researches which used random forest algorithm for binary classification, this paper divided output variables into five groups, whose forecasted results provided more information. The purposed the novel method has three steps in this research. Firstly, this paper divided the increment rate of gold price to five concussion intervals based on the historical data. Secondly, on the basis of simple correlation analysis, this research choose five indexes out of those aforementioned indexes. Finally, this paper proposes a new idea of stepwise backward variable selection to find the key influence factors and the excellent result of gold price fluctuation trend prediction.

The rest of this paper is organized as follows. Section 59.2 presents the methodology of Random Forest. Section 59.3 provides the experimental process and results Finally, in Sect. 59.4, conclusions will be drawn.

59.2 Methodology

Random Forest is a popular and very efficient algorithm, based on model aggregation ideas, for both classification and regression problems, introduced by Breiman [5]. It belongs to the family of ensemble methods, appearing in machine learning at the end of nineties. Let us briefly recall the statistical framework by considering a learning set $L = \{(X_1, X_2), \ldots, (X_n, Y_n)\}$ made of n i.i.d. observations of a random vector (X, Y). Vector $X = (X_1, \ldots, X_p)$ contains predictors or explanatory variables, say $X \in R_p$, and $X \in Y$ where Y is either a class label or a numerical response. For classification problems, a classifier t is a mapping t: $R_p \longrightarrow Y$, while for regression problems, we suppose that $Y = s(X) + \varepsilon$ with $E[\varepsilon|X] = 0$ and s the so-called regression function. Random Forest is a model building strategy providing estimators of either the Bayes classifier, which is the mapping minimizing the classification error View the MathML source, or the regression function.

The principle of Random Forest is to combine many binary decision trees built using several bootstrap samples coming from the learning sample L and choosing randomly at each node a subset of explanatory variables X. More precisely, with respect to the well-known CART1 model building strategy performing a growing step followed by a pruning one, two differences can be noted. First, at each node, a given number (denoted by mtry) of input variables are randomly chosen and the best split is calculated only within this subset. Second, no pruning step is performed so all the trees of the forest are maximal trees.

RF algorithm becomes more and more popular and appears to be very powerful in a lot of different applications even if it is not clearly elucidated from a mathematical point of view. Nevertheless, Breiman sketches an explanation of the good performance of Random Forest [5] related to the good quality of each tree together with the small correlation among the trees of the forest, where the correlation between trees is defined as the ordinary correlation of predictions on so-called out-of-bag samples. The OOB sample is the set of observations which are not used for building the current tree. It is used to estimate the prediction error and then to evaluate variable importance.

59.3 Experiment

59.3.1 Data Preprocessing

Relevant historical data were collected from IHS Global Insight Inc, website of World Bank Group, website of the US Federal Reserve and website of the International Monetary Fund, ranges from January-1988 to March-2015. The monthly averages of gold price were selected as our material due to it could present the price lever of the every month better. There were 326 samples in total before data preprocessing.

As mentioned above, this paper selected seven variables to explain and predict the trend of gold price (GP): US dollar index (USDX), the crude oil price (COP), Dow Jones Industrial Average (DJIA), the CPI of US (USCPI), the prices of US ten year bond futures (US10BFP), the Hang Seng Index (HIS) and the Standard & Poor's 500 Index (S&P500). The purpose of data preprocessing was to get the correct input variables which could provide enough information to predict the trend of gold price. Firstly, we took average value of daily indexes to translate them into monthly indexes. Because it is the increment of seven indexes rather than index values that affect the trends of raise or fall of the gold price, we processed the data to get the increment of seven index and gold price. Then, we grouped the growth rate of gold price. In order to make the amount of data in each group are roughly the same, we set the following grouping interval: less fluctuation: $C_1 = (-0.7\,\%, 0.7\,\%)$; a modicum of increase: $C_2 = (0.7\,\%, 3.1\,\%)$; a large increase: $C_3 = (3.1\,\%, +\infty)$; a modicum of decrease: $C_4 = (-2.2\,\%, -0.7\,\%)$; a large decrease: $C_5 = (-\infty, -2.2\,\%)$. Each group corresponded to a concussion interval of gold price.

59.3.2 Simple Correlation Analysis

Firstly, simple correlation analysis was adopted to the growth rate of gold price and the increment of seven indexes. The confidence level was set to 95 %. We chose the indexes $(I_1, I_2, \ldots, I_n)$ which have significant correlation with gold price. The indexes we chose were used to build the initial combination.

59.3.3 Principal Process

The purpose of this part was to yield the prediction of the concussion interval of gold price with the lead-time of one month. Random Forest classification algorithm was used to predict the concussion interval of gold price. The basic idea of Random Forest classification: Firstly, use the Bootstrap sampling to extract B samples from the original data set, and the sample size of each sample is the same as the original data set. Then, set up B trees for B samples respectively and get B results. Finally, the average value of the B results is obtained to get the final prediction result. Random Forest is a collection of $\{T_1(X), K, T_B(X)\}$ of B trees, in which $X = \{x_1, k, x_p\}$ is P-dimensional feature vector. Collection will produce B results.

We randomly sampled from the original data set to construct a training set and the size of training set was set to be 70 % of the size of original data set. Finally, the independent variables of the test set were input to the established Random Forest model and got the prediction of the group of concussion interval of gold price. Then, we compared the prediction results with the actual price to detect the performance of the model. The accuracy rate was chose as evaluation indicator for each model.

In order to find the critical influence factors, a method of stepwise backward variable selection was conducted. First, we used the increase and decrease of initial combination with indexes as input variable and measured the performance of the model. According to the performance, we chose all combinations with $(n-1)$ indexes from $(I_1, I_2, \ldots, I_n)$ as input variables. Then, all combinations with $(n-2)$ indexes were chose and the procedures were carried on repeatedly until the conformance of the combination would not change significantly.

59.3.4 The Result of Simple Correlation Analysis

The results are shown in Table 59.1:

After analyzing the result of simple correlation, we knew that among seven indexes, the correlations between the concussion percentage of gold price and the increase and decrease of USDX, COP, DJIA, USCPI and S&P500 were significant at the 0.05 level (2-tailed).

59.3.5 The Result of Principal Process

(1) We used the combination of the increment of USDX, COP, DJIA, USCPI and S&P500 as the input variable. The result is shown (Table 59.2):

We discerned from the table that the concussion interval of the gold price could be analyzed and predicted well with the combination of the increment of USDX, COP, DJIA, USCPI and S&P500 (the accuracy rates get 1). We used them to build the initial combination.

(2) Then, all combinations with four indexes from USDX, COP, DJIA, USCPI and S&P500 were chose as input variables. And the results are as follows (Table 59.3):

The results showed that the concussion interval of the gold price could also be predicted very well with the combination of four of the increment of USDX, COP, DJIA, USCPI and S&P500.

Table 59.1 The correlation between the growth rate of gold price and the increment of seven indexes

		A_1	A_2	A_3	A_4	A_5	A_6	A_7
Y	Pearson Correlation	−0.341**	0.212	−0.158	0.246	0.073	0.092	−0.145
	Sig.(2-tailed)	0.000	0.000	0.004	0.000	0.186	0.097	0.009
	N	326	326	326	326	326	326	326

A_1: the increment of USDX; A_2: the increment of COP; A_3: the increment of DJIA; A_4: the increment of USCPI; A_5: the increment of US10BFP, A_6: the increment of HIS, A_7: the increment of S&P500; Y: the growth rate of gold price; **: Significant under the 0.01 level

Table 59.2 The result of prediction with the combination of USDX, COP, DJIA, USCPI and S&P500

	A.M	A.S	A.C_1.M	A.C_1.S	A.C_2.M	A.C_2.S	A.C_3.M	A.C_3.S	A.C_4.M	A.C_4.S	A.C_5.M	A.C_5.S
USDX, COP, DJIA, USCPI and S&P500	1	0	1	0	1	0	1	0	1	0	1	0

A.M: Accuracy.mean; A.S: Accuracy.sd; A.C_1.M: Accuracy.C_1.mean; A.C_1.S: Accuracy.C_1.sd; A.C_2.M: Accuracy.C_2.mean; A.C_2.S: Accuracy.C_2.sd; A.C_3.M: Accuracy.C_3.mean; A.C_3.S: Accuracy.C_3.sd; A.C_4.M: Accuracy.C_4.mean; A.C_4.S: Accuracy.C_4.sd; A.C_5.M: Accuracy.C_5.mean; A.C_5.S: Accuracy.C_5.sd

Table 59.3 The result of prediction with the combination of four indexes

	A.M	A.S	A.C_1.M	A.C_1.S	A.C_2.M	A.C_2.S	A.C_3.M	A.C_3.S	A.C_4.M	A.C_4.S	A.C_5.M	A.C_5.S
USDX, COP, DJIA and USCPI	1	0	1	0	1	0	1	0	1	0	1	0
USDX, COP, DJIA and S&P500	1	0	1	0	1	0	1	0	1	0	1	0
USDX, COP, USCPI and S&P500	1	0	1	0	1	0	1	0	1	0	1	0
COP, DJIA, USCPI and S&P500	1	0	1	0	1	0	1	0	1	0	1	0
USDX, DJIA, USCPI and S&P500	1	0	1	0	1	0	1	0	1	0	1	0

A.M: Accuracy.mean; A.S: Accuracy.sd; A.C_1.M: Accuracy.C_1.mean; A.C_1.S: Accuracy.C_1.sd; A.C_2.M: Accuracy.C_2.mean; A.C_2.S: Accuracy.C_2.sd; A.C_3.M: Accuracy.C_3.mean; A.C_3.S: Accuracy.C_3.sd; A.C_4.M: Accuracy.C_4.mean; A.C_4.S: Accuracy.C_4.sd; A.C_5.M: Accuracy.C_5.mean; A.C_5.S: Accuracy.C_5.sd

Table 59.4 The result of prediction with the combination of three indexes

	A.M	A.S	A.C_1.M	A.C_1.S	A.C_2.M	A.C_2.S	A.C_3.M	A.C_3.S	A.C_4.M	A.C_4.S	A.C_5.M	A.C_5.S
DJIA, USCPI and S&P500	1	0	1	0	1	0	1	0	1	0	1	0
COP, USCPI and S&P500	0.9993	0.0026	0.9990	0.0067	1	0	0.9989	0.0074	0.9995	0.0048	0.9989	0.0074
COP, DJIA and USCPI	0.9991	0.0029	1	0	1	0	0.9995	0.0053	1	0	0.9958	0.014
COP, DJIA and S&P500	1	0	1	0	1	0	1	0	1	0	1	0
USDX, USCPI and S&P500	0.9978	0.0042	1	0	0.9989	0.0074	1	0	1	0	0.9895	0.0212
USDX, DJIA and USCPI	0.9945	0.0065	1	0	0.9889	0.0240	0.9995	0.0053	0.9990	0.0067	0.9842	0.0255
USDX, DJIA and S&P500	1	0	1	0	1	0	1	0	1	0	1	0
USDX, COP and USCPI	0.9994	0.0024	1	0	0.9995	0.0053	0.9989	0.0074	0.9990	0.0067	0.9995	0.0053
USDX, COP and S&P500	0.9983	0.0046	0.9986	0.0082	0.9995	0.0053	0.9995	0.0053	0.9986	0.0082	0.9953	0.0151
USDX, COP and DJIA	0.9972	0.0046	0.9924	0.0175	1	0	1	0	0.9943	0.0156	1	0

A.M: Accuracy.mean; A.S: Accuracy.sd; A.C_1.M: Accuracy.C_1.mean; A.C_1.S: Accuracy.C_1.sd; A.C_2.M: Accuracy.C_2.mean; A.C_2.S: Accuracy.C_2.sd; A.C_3.M: Accuracy.C_3.mean; A.C_3.S: Accuracy.C_3.sd; A.C_4.M: Accuracy.C_4.mean; A.C_4.S: Accuracy.C_4.sd; A.C_5.M: Accuracy.C_5.mean; A.C_5.S: Accuracy.C_5.sd

Table 59.5 The result of prediction with the combination of two indexes

	A.M	A.S	A.C_1.M	A.C_1.S	A.C_2.M	A.C_2.S	A.C_3.M	A.C_3.S	A.C_4.M	A.C_4.S	A.C_5.M	A.C_5.S
USCPI and S&P500	0.9718	0.0144	0.9810	0.0262	0.9784	0.0352	0.9690	0.0367	0.9733	0.0320	0.9563	0.0430
DJIA and S&P500	1	0	1	0	1	0	1	0	1	0	1	0
DJIA and USCPI	0.9677	0.0167	0.9781	0.0282	0.9821	0.0272	0.9763	0.0329	0.9810	0.0287	0.9184	0.0552
COP and USCPI	0.9599	0.0191	0.9857	0.0249	0.9526	0.0433	0.9505	0.0501	0.9705	0.0350	0.9363	0.0520
COP and S&P500	0.9998	0.0010	1	0	1	0	0.9995	0.0053	1	0	1	0
DJIA and COP	0.9998	0.0010	1	0	1	0	1	0	1	0	0.9995	0.00523
USDX and USCPI	0.8692	0.030	0.860	0.0716	0.8911	0.0670	0.8889	0.0643	0.8724	0.0645	0.8342	0.0757
USDX and S&P500	0.9872	0.0113	0.9971	0.0132	0.9963	0.0135	0.9868	0.0263	0.9886	0.0215	0.9658	0.0346
USDX and DJIA	0.9909	0.0101	0.9986	0.0082	0.9811	0.0313	0.9947	0.0159	0.9976	0.0104	0.9811	0.0285
USDX and COP	0.9953	0.0074	0.9933	0.0166	0.9947	0.0175	0.9995	0.0053	0.9976	0.0104	0.9911	0.0237

A.M: Accuracy.mean; A.S: Accuracy.sd; A.C_1.M:Accuracy.C_1.mean; A.C_1.S: Accuracy.C_1.sd; A.C_2.M: Accuracy.C_2.mean; A.C_2.S: Accuracy.C_2.sd; A.C_3.M: Accuracy.C_3.mean; A.C_3.S: Accuracy.C_3.sd; A.C_4.M: Accuracy.C_4.mean; A.C_4.S: Accuracy.C_4.sd; A.C_5.M: Accuracy.C_5.mean; A.C_5.S: Accuracy.C_5.sd

Table 59.6 The result of prediction with the combination of one indexes

	A.M	A.S	A.C_1.M	A.C_1.S	A.C_2.M	A.C_2.S	A.C_3.M	A.C_3.S	A.C_4.M	A.C_4.S	A.C_5.M	A.C_5.S
USCPI	0.5573	0.0380	0.6610	0.0929	0.4905	0.0928	0.5968	0.1034	0.5533	0.0817	0.4742	0.1027
S&P500	0.9962	0.0049	1	0	1	0	0.9979	0.0104	1	0	0.9821	0.0251
DJIA	0.9999	0.0010	1	0	1	0	0.9995	0.0053	1	0	1	0
COP	0.8715	0.0285	0.8895	0.0645	0.9068	0.0673	0.8963	0.0623	0.9067	0.0558	0.7526	0.0814
USDX	0.4222	0.0421	0.4081	0.1075	0.4832	0.1062	0.2637	0.0861	0.5262	0.1069	0.4205	0.1032

A.M: Accuracy.mean; A.S: Accuracy.sd; A.C_1.M:Accuracy.C_1.mean; A.C_1.S: Accuracy.C_1.sd; A.C_2.M: Accuracy.C_2.mean; A.C_2.S: Accuracy.C_2.sd; A.C_3.M: Accuracy.C_3.mean; A.C_3.S: Accuracy.C_3.sd; A.C_4.M: Accuracy.C_4.mean; A.C_4.S: Accuracy.C_4.sd; A.C_5.M: Accuracy.C_5.mean; A.C_5.S: Accuracy.C_5.sd

(3) To further reduce the number of indicators, we chose the combinations with three of the USDX, COP, DJIA, USCPI and S&P500 (Table 59.4).

The highest accuracy rate was 1 and was for DJIA, USCPI and S&P500, COP, DJIA and S&P500 and USDX,DJIA and S&P500. According to the results, we found that every combination with highest accuracy rate had the indexes of DJIA and S&P500.

(4) In order to verify the results above, we chose the combinations with two of the USDX, COP, DJIA, USCPI and S&P500 (Table 59.5).

According to the table above, we found that though the accuracy rate for every combination was high, the combination of the increment of DJIA and S&P500 had the best prediction performance, which verified the above conclusion.

(5) In order to obtain the minimum number of indicators, we conducted the experiment with single input variable (Table 59.6).

DJIA had the best prediction performance (0.9999), then was the S&P500 (0.9962), and USDX was the worst (0.4222). The performance of the prediction with single index was less accurate than the combination of the increment of DJIA and S&P500.

59.4 Conclusion

There are 4 conclusions can be drawn from the experiment:

(1) The experiment achieved high prediction accuracy, which indicated that the data mining is a powerful method to predict the trends of increase or decrease of the gold price;

(2) Random Forest has strong adaptability to complex data. Random forest model has high precision and is worth popularizing and applying.

(3) The results show that the combination of Dow Jones Industrial Average (DJIA) and the Standard & Poor's 500 Index (S&P500) reveals a favorable capability in forecasting the trend of gold price. The results supply some information for future studies;

(4) The method of stepwise backward variable selection has developed a new idea for finding the critical influence factors, which provides new speculations for future research.

References

1. Aye G, Gupta R et al (2015) Forecasting the price of gold using dynamic model averaging. Int Rev Financ Anal 41:257–266
2. Ballings M, Poel D et al (2015) Evaluating multiple classifiers for stock price direction prediction. Expert Syst Appl 42:7046–7056
3. Baur D, Beckmann J, Czudaj R (2014) Gold price forecasts in a dynamic model averaging framework-have the determinants changed over time? Ruhr Economic Papers pp 506–517

4. Bentes S (2015) Forecasting volatility in gold returns under the GARCH, IGARCH and figarch frameworks: new evidence. Phys A Stat Mech Appl 438:355–364
5. Breiman L (2001) Random forests. Mach Learn 45:5–32
6. Chen W, Shih J (2006) Comparison of support-vector machines and back propagation neural networks in forecasting the six major asian stock markets. Electron Financ 1(1):49–67
7. Gokmenoglu K, Fazlollahi N (2015) The interactions among gold, oil, and stock market: evidence from S&P500. Procedia Econ Financ 25:478–488
8. Goodman B (1956) The price of gold and international liquidity. Finance 11:15–28
9. Levin E, Wright R (2006) Short-run and long-run determinants of the price of gold. World Gold Council
10. Li B (2014) Research on wnn modeling for gold price forecasting based on improved artificial bee colony algorithm. Comput Intell Neurosci 1:230–235
11. Liu S, Tang T et al (2015) Low-frequency volatility in China's gold futures market and its macroeconomic determinants. Math Probl Eng 3:1–8
12. Pang S (2009) Hong kong property market analysis. International Conference on Construction & Real Estate Management
13. Shafiee S, Topal E (2010) An overview of global gold market and gold price forecasting. Resour Policy 35(3):178–189
14. Sjaastad L, Scacciavillani F (1996) The price of gold and the exchange rate. J Int Money Financ 15(6):879–897
15. Smith G (2010) The price of gold and stock price indices for the United States. In: World Gold Council
16. Tsibouris G, Zeidenberg M (1995) Testing the efficient markets hypothesis with gradient descent algorithms. Refenes Ap Neural Networks in the Capital Markets. Wiley, New York, pp 127–136
17. Zhang F, Liao Z (2014) Gold price forecasting based on rbf neural network and hybrid fuzzy clustering algorithm, vol 241. Springer, Berlin
18. Zhang J, Liu C, Sun B (2010) Research on prediction of the price of gold based on artificial neural network algorithm. Econ Probl 1:110–114

Chapter 60
Exchange Rate and China's OFDI in Asian Developing Countries: A Dynamic Panel Data Analysis

Haiyue Liu, Siyuan Li and Xiaolan Chen

Abstract This paper exams the effect of exchange rate (ER) on China's outward foreign direct investment (OFDI). To examine the relationship between ER and China's OFDI, the panel data of 34 Asian developing countries from 2003 to 2013 is analyzed by System GMM model. The results show that China's OFDI to Asian developing countries has significantly positive association with ER level and volatility. However, the ER exchange rate expectation is not a sensitive stimulus for Chinese OFDI in Asian developing countries in the long run.

Keywords Voice behavior · Asian developing countries · Exchange rate

60.1 Introduction

During 2003–2013, China's total outward foreign direct investment (OFDI) has increased from 11.79 million US dollars to 73200 million US dollars, which has doubled in recent five years. In 2010, China became the second largest OFDI country in the world (UNCTAD, 2011), and President Xi addressed that China's OFDI will reach the amount of 1.25 trillion within ten years in 2014 APEC.

A large amount of China's OFDI flows into Asian developing countries especially those who have partnership with China, and the amount accounts for over 60 % of China's total OFDI in 2009. Hong Kong and ASEAN countries with relatively low GDP level are considered as China's important OFDI recipients (See Fig. 60.1 (Source: China's Ministry of Commerce, 2009 Statistical Bulletin of China's Outward Foreign Direct Investment)).

From the aspect of industry distribution, China's FDI to ASEAN countries is mainly on four sectors: power and other utilities, wholesale and retailing,

H. Liu
Business School, Sichuan University, Chengdu 610064, People's Republic of China

S. Li · X. Chen (✉)
Economics School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: chenxiaolan@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_60

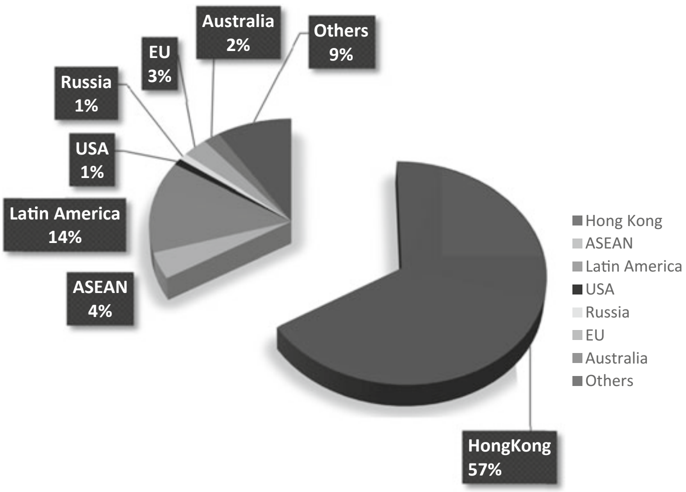


Fig. 60.1 China's OFDI into major economies

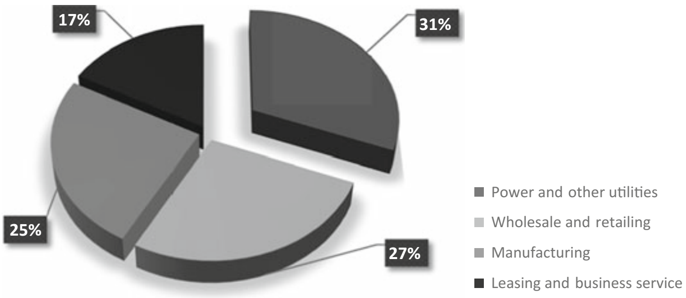


Fig. 60.2 Sectorial share of China's FDI in ASEAN countries

manufacturing, leasing and business service (See Fig. 60.2 (Source: China's Ministry of Commerce, 2009 Statistical Bulletin of China's Outward Foreign Direct Investment)).

When Chinese firms invest in Asian countries, the highest risk that Chinese firms confront is the investment environment risk, including political risks, exchange rate risks (ER risks), credit risks, legal risks and nature risks. ER risks causes the most loss [15]. For example, there are 1050 listed companies suffering from exchange loss in 2012, and the loss accounts for 60 % of all the listed companies.

This paper aims to examine the effect of ER on China's OFDI. We choose Asian developing countries as the main study group because of its role being the import recipient of Chinese OFDI after Chinese government putting more attention on the "One Belt One Road" Initiative. Further, we optimize the ER measurement by considering level, volatility and expectation in our model, which will add new evidence to the existing empirical literature. In addition to this, a dynamic estimation framework is used instead of a static analysis.

This paper is organized as follows. Section 60.1 features the magnitudes and patterns of China OFDI as well as Asian developing countries' characteristics as investment recipient. Section 60.2 reviews the relevant theoretical and empirical literature. Section 60.3 describes the empirical model and data. In Sect. 60.4, we will present the key empirical results. And we conclude in the final section.

60.2 Literature Background

Theoretical arguments about the exchange rate's effect on OFDI are controversial. Many literature points out that exchange rate variations could promote overseas investment [6, 13]. While other empirical studies suggest that uncertainty of exchange rate will instead suppress OFDI. These arguments claim that unpredictable fluctuations in the exchange rate introduce additional uncertainty into both the production costs and future revenues of overseas operations, deterring potential investors. Some scholars declare that currency volatility deters the entry of multinational firms by increasing the "option value" [5, 8, 9, 16].

Although Chinese OFDI has become a more interesting topic, relatively few empirical studies have been conducted. Buckley et al. [4] used panel data on Chinese FDI to 49 countries during 1984–2001. They find that exchange rate level, distance from China and total FDI as a share of GDP have no significant importance to Chinese FDI. Jin [12] found that the appreciation of RMB promotes FDI after the reforms in the exchange rate regime in 2005. Hu [11] used a panel data including 49 countries during 2003–2010. They find out that Chinese OFDI is positively related to exchange rate level. Xia [19] concluded that RMB exchange rate level would stimulate Chinese OFDI and increase firm's profit. ER volatility will worsen the investment environment of the host country and cause less foreign investment [11, 14, 15].

Previous literature on ER and Chinese OFDI is limite' behavior are not discussed. Therefore we attempt to fill in the gap by examining ER level, volatility and expectation in a specific region—Asian developing countries. Furthermore, the previous study confined their focus on the ER volatility's effect on OFDI, only few of them took ER expectation (long run effect) into consideration. This paper will use not only the mean as the measurement of ER but also the skewness as the measurement of ER expectation to deepen the previous research and to put forward some effective advice for Chinese investors.

60.3 Variable Explanation and Model Description

To investigate the effect of possible exchange rate risk on direct investment, we use panel data of 34 countries over the period 2003–2013. This data is collected mainly from IMF database. The measurement proceeds as follows.

60.3.1 Dependent Variables

The dependent variable for our analysis is the yearly Chinese OFDI flows to the host country during our study period. We use $\text{Log\_FDI}_{\text{it}}$, the natural logarithm of every year's real FDI flows from China to each recipient 'economy i', expressed in billions of dollar (the CPI index is used to deflate the nominal values).

60.3.2 Independent Variables

In order to reflect the exchange rate more comprehensively, we employed three dimensions of exchange rate: $\text{Log\_Mean}_{\text{it}}$, $\text{Volitility}_{\text{it}}$, and $\text{Skewness}_{\text{it}}$.

(1) Log_Mean

We use $\text{Log\_Mean}_{\text{it}}$ to reflect the level of exchange rate between China and the recipient country. It is the natural logarithm of the average of monthly nominal exchange rates around 'year t' (that includes monthly observations for 'year t' and '$t-1$') for 'country i'. It represents the relative price difference between the host country and Chinese aggregated goods. The larger $\text{Log\_Mean}_{\text{it}}$ means more appreciation in RMB. We thus expect a positive relationship between the exchange rate level and China's outward investment as higher RMB value can encourage Chinese outward investment.

(2) Volatility

$\text{Volitility}_{\text{it}}$ is the standard deviation of nominal monthly exchange rates around 'year t' for 'country i'. 24 monthly observations in 'year t' and '$t-1$' are used to calculate standard deviation, and the higher value means higher volatility. Given the previous literature results, the sign of $\text{Volitility}_{\text{it}}$ is undefined due to the influence of the host country's level of economic development and industry's specifics.

(3) Skewness

Inspired by Deseatnicov and Akiba [7], this paper employs $\text{Skewness}_{\text{it}}$ as an additional important variable to measure exchange rate. $\text{Skewness}_{\text{it}}$ is a third moment of monthly exchange rates around 'year t' for 'country i' and calculated by 24 monthly observations in 'year t' and '$t-1$' This variable is expected to capture the expectation effect of ER as 'relatively large exchange rate shocks predominantly in one direction could create expectations of reversal' [18]. A positive sign is associated with a large number of RMB appreciation shocks, which in turn may lead to the expectation of RMB depreciation and thus an increase in the future value of repatriated profits. Hence, in this paper, OFDI is expected to be associated positively with $\text{Skewness}_{\text{it}}$.

60.3.3 Other Control Variables

(1) Political Environment (*PE*)

International Country Risks Index is used to capture the effect of political risks. PE_{it} represents political environment for 'country *i*' at 'year *t*' and has recently been emphasized as one of the worthy issues of investigation in international economics. Data from ICRG is used to calculate the political index, ranging from 0 to 100. The higher score is, the lower political risk is. It consists of multiple dimensions including government stability, socioeconomic conditions, country's investment profile, military in politics, bureaucracy quality, and etc. (See Table 60.1). The multiple dimensionality of composite index is likely to have different impacts on FDI and the index used in the paper is a proper measure to test the sensitivity of China' s OFDI to political risk in Asian developing countries.

(2) Log_GDP

$\text{Log\_GDP}_{\text{it}}$ is the natural logarithm of GDP in 'country *i*' in 'year *t*'. This variable serves as a proxy for sales and approximately represents the market size for 'country' in 'year *t*'. A positive sign of GDP on OFDI is expected.

(3) Log_GDP_PC

Working capital is another important factor for FDI flows. Availability of low cost labor is expected to stimulate FDI of vertical type where the cheap wage is considered to be of high importance. GDP per capita is a proxy variable of labor cost. In this paper, we use the logarithm of GDP per capita in 'country *i*' at 'time *t*' ($\text{Log\_GDP\_PC}_{\text{it}}$, deflated by CPI) to represent the human capital of the host economy. The impact of $\text{Log\_GDP\_PC}_{\text{it}}$ is expected to be negative as higher labor cost is expected to discourage FDI flows.

(4) Openness

Openness is the ratio of the sum of imports and exports to GDP. In general the impact of openness is linked to the type of FDI [17]: the openness is expected to have negative impacts on horizontal FDI (implying that trade barriers are high) while it is expected to have positive influence on vertical-type FDI (implying that trade barriers are low).

(5) Log_IR

Log_IR is the logarithms of real interest rate in China. We use this variable to measure the opportunity cost of company's investment. Log_IR is expected to have a negative sign as a higher cost of funds tends to reduce incentive for outward FDI. To explain the variables more explicitly, we give the following Table 60.1.

Table 60.1 Variables description

Var. name	Meanings	Calculation	Data source
Log_Mean	The logarithm of average level of the exchange rate during a certain period	Log_Mean = $\frac{1}{24}\ln(\sum_{t-24}^{t} ER_n)$	IMF IFS statistics
Volatility	Fluctuation of exchange rate	Volatility = $\frac{1}{24}\sum_{t-24}^{t}(ER_n - \overline{ER_n})^2$	IMF IFS statistics
Skewness	Expectation of ER level	Skewness = $\frac{1}{24}\sum_{t-24}^{t}(ER_n - \overline{ER_n})^3$	IMF IFS statistics
PE	International Country Risks Index	$PE = \ln\sum_{0}^{12} PE_n$	ICRG
Log_GDP	Real Gross Domestic Product (by CPI)	Log_GDP = $\ln\left(\frac{\text{Nominal GDP}}{\text{CPI}}\right)$	WB WDI
Log_GDP_PC	Substitute variable of income level	Log(_GDP_PC_CPI) = $\ln\left(\frac{\text{GDP}}{\text{Population}\times\text{CPI}}\right)$	WB WDI
Openness	Openness in Constant Prices	Openness = $\frac{\text{Exprot+Import}}{\text{GDP}}$	WB WDI
Log_IR	Measurement of opportunity cost	Log_IR = ln(Interest Rate)	IMF IFS statistics

60.3.4 Empirical Model and Data

In order to investigate the possible financial risk's effect on direct investment, Generalized Method of Moments (GMM) analysis is employed, and the basic model for GMM is specified in a reduced form as:

$$y_{it} = \delta y_{i,t-1} + X'_{it}\beta + \varepsilon_{it},$$

where y_{it} is the logarithm of annual outward FDI from China into a host 'country i' at 'time t'; X'_{it} denotes an vector of exogenous variables, which vary in both cross-section and time dimension; δ is a scalar; $y_i, t-1$ is the lagged dependent variable; ε it is the stochastic error term, which is assumed to be uncorrelated over all i and t. Therefore, our empirical model can be described as:

$$\begin{aligned} Log\_FDI_{it} = {} & \delta(\text{Log\_FDI})_{i,t-1} + \beta_1 PE_{it} + \beta_2\text{Log\_GDP}_{it} + \beta_3\text{Log\_IR}_{it} + \\ & \beta_4\text{Log\_GDP\_PC}_{it} + \beta_5\text{Openness}_{it} + \beta_6\text{Log\_Mean}_{it} + \\ & \beta_7\text{Volatility}_{it} + \beta_8\text{Skewness}_{it} + \varepsilon_{it}. \end{aligned}$$

Table 60.2 Statistics summary

Variable	Observations	Std. error	Mean	Min	Max
Log_FDI(−1)	250	0.0303	7.0591	0	11.8257
PE	250	3.3715	4.1423	3.5028	4.4248
Log_GDP	307	0.4062	15.7937	9.4485	19.052
Log_IR	204	0.2135	1.1396	0.46813	1.7838
Log_GDP_PC	337	1.7017	8.1911	1.1209	6.9057
Openness	344	2.4051	4.2558	3.0573	5.2247
Log_Mean	308	1.2156	1.564	−3.0693	8.1145
Volatility	308	0.0019	14.198	0	924.0074
Skewness	308	0.0752	0.093	−4.8862	3.7008

With considering possible heteroscedasticity, autocorrelation and endogeneity simultaneously, Panel data analysis is employed to disclose the nature of the FDI. We choose dynamic panel model by adding lagged FDI flow as an additional regressor. Our database consists of a repeated cross-section of 34 Asian developing countries (denoted with $i = 1, \ldots, N$) in 11periods from 2003 to 2013. The total number of observations is 374, which is adequate to generate robust estimations for the scope of the analysis.The summary statistics is reported in Table 60.2.

To deal with the possible issues of autocorrelation, endogeneity and heteroscedasticity, we adopted a commonly used method for dynamic panels, the GMM estimator proposed by Arellano and Bond [2]. Under the model setting, the fixed effects are eliminated using first differences, and an instrumental variable estimation of the differenced equation is performed. However, first difference approach has apparent weakness when using unbalanced data. Our sample contains some missing data points. Thus, we followed another approach proposed by Arellano and Bover [3] namely "forward orthogonal deviations". In contrast to the "first difference", it subtracts the average of all future available observations of variable. Then, we used GMM style instruments as proposed by Holtz-Eakin, Newey et al. [10] in order to overcome possible endogeneity of the explanatory variables. A Hansen J-test of over identifying restrictions for the selected instruments was performed next. All the regressions were shown to be robust according to the criterion. Thus, we do not include any additional (external) instruments.

60.4 Estimation Results and Major Findings

The estimation results are showed in Table 60.3.

From the estimation, we proved some possible linkages between ER and Chinese OFDI.

Table 60.3 Exchange rate risk effects on Chinese OFDI, 34 countries

Variable	Coefficient	Std. error	t-statistic	Prob
Log_FDI(−1)	−0.1429	0.0303	−4.7139	0.0001
PE	2.0555	3.3715	0.6097	0.5436
Log_GDP	0.4185	0.4062	1.0302	0.3055
Log_IR	−0.5289	0.2135	−2.4769	0.0157
Log_GDP_PC	6.6757	1.7017	3.9229	0.0002
Openness	2.8307	2.4051	1.1769	0.0004
Log_Mean	7.6944	1.2156	6.3295	0.0002
Volatility	0.0108	0.0019	5.754	0.0002
Skewness	0.0035	0.0752	0.046	0.9634
Effects specification				
Cross-section fixed (orthogonal deviations)				
Mean dependent var	−0.8441	S.D. dependent var	1.3418	
S.E. of regression	1.6542	Sum squared resid	257.2158	
J-statistic	34.6596	Instrument rank	35	

As to check the robustness of our results, we also run an OLS model.The result reassure our findings from SYS-GMM

(1) How does exchange rate level influence China's OFDI?

The coefficient of Log_Mean is significantly positive, which means that appreciation in RMB will promote China's OFDI to Asian developing countries. This finding meets our expectations. The explanation lies in the relatively lower 'sunk cost' due to higher RMB value. For a company that invests abroad, the asset acquisition cost will be decreased if the currency in home country appreciates.

Moreover, the high exchange rate level will limit the volume China's direct export. Liu, Jiang, and Tang [20] pointed out that Chinese exchange rate level appreciated 45 % from 1994 to 2012. As Chinese exchange rate level appreciates, multinational companies will find another way to get into oversea market besides exporting. As the substitute of export, outward foreign direct investment becomes the choice for Chinese investors. In this case, high exchange rate level will stimulate OFDI.

(2) Does the fluctuation of exchange rate affect China's OFDI?

Different from what we commonly believe, Volatility (fluctuation of exchange rate) has a positive and significant effect on China's OFDI. It shows that China's multinational companies will be stimulated if they find the exchange rate risk is becoming higher. High yield comes with high exchange rate volatility risk.Many financial instruments can be used to neutralize exchange rate fluctuation risks. Thus, Chinese investors could tolerate an increase in the financial risk and it can actually become an incentive to invest due to higher expected profits.

Another explanation proposed by Deseatnicov and Akiba [7] was that higher uncertainty would promote FDI as substitute to exports. The explanation lies in the redistribution of production channel thus replacing direct export activity.

(3) How does exchange rate expectation affect China's OFDI?

The effect of Skewness(exchange rate expectation) is positive but not significant. This can be used as an explanation for the extreme loss that China's multinational companies suffer from caused by exchange rate fluctuation. Although China's multinational companies are concerned with exchange rate level, they fail to take the expectation into consideration. As we find above, China's companies tend to be risk lovers, ignorance of future trend of exchange rate level make Chinese investors expose to higher risk.

(4) What factors can also influence China's OFDI to Asian developing countries?

Log_IR has a negative relationship with OFDI. Higher interest rate in China will discourage China's OFDI. This phenomenon can be explained from two aspects. First, higher interest rate means that an investor who wants to borrow money from Chinese capital market to invest abroad will face higher financial cost. Second, a higher interest rate brings higher opportunity cost. The increase of interest rate in home country often means a higher yield generated from domestic investing, which in turn demotivates overseas investment.

Log_GDP_PC is the measure of human capital cost in host country. We assume that higher human capital cost will discourage OFDI. However, the estimation results show that higher GDP per capita will encourage OFDI. This is surprising but also explainable. GDP per capita can reflect the quality of working force in the host country. Asian developing countries as a whole are relatively associated with low labor quality. It is rational for investors to invest in countries with higher labor quality to ensure more promising products.

Log_GDP has positive but not significant influence on OFDI. Higher GDP level means higher economy level. This kind of developing advance can create more chances to make money and contribute to the positive relationship. On the other hand, the insignificant influence can be explained in both ways. One is that Chinese investors in Asian developing countries are more attracted by poor infrastructure facilities as well as a relatively abundant natural recourses endowment instead of GDP level. Another explanation is that although Asian developing countries have low GDP level, they maintain relatively high GDP grows rate,which provide market potential and attract Chinese OFDI. Hence, Chinese investors tend to ignore the overall GDP level.

Openness has a positive influence on OFDI. This can be understood easily because a host country with more imports and exports is more willing to absorb investment and may have more favorable policy for foreign investors.

PE reflects the comprehensive political risks of a host country. Although it is commonly believed that better political environment can attract more FDI, the estimation results show insignificance between PE and Chinese OFDI. Chinese OFDI in Asian developing countries are most promoted by government projects and strategies, and Chinese investment in this area is often policy-oriented rather than market-oriented. Another explanation could be that Chinese investors are indifferent with political risks because they are competitive in the counties with worse political and social environment [1, 13].

60.5 Concluding Remarks

In this paper, we examine a panel data with 34 Asian developing countries from 2003 to 2013 to study the relationship between ER and Chinese OFDI, and a dynamic system GMM model is employed. Major findings suggest that China's OFDI to Asian developing countries has significantly positive association with ER level and volatility. However, the ER exchange rate expectation is not a sensitive stimulus for Chinese OFDI in the long run. As for other determinants, PE and GDP are found to be insignificantly related to Chinese OFDI, while home country's real interest rate is negatively significant and GDP per Capita (Labor cost) is positively significant related to Chinese OFDI.

As Chinese government is strongly promoting investment in Asian developing countries, future policies oriented to stimulate investment will be put forward to facilitate Chinese multinationals' cross-border investments. As a matter of fact, foreign direct investment decision belongs to firm's behavior indeed. Except for government policy, the Chinese multinationals should focus more on market forces in case of choosing investment destination and timing. More RMB financial tools and instruments should be developed to support the financing and investing purpose of Chinese investors to help safeguard the ER fluctuation and possible financial uncertainty. A more open capital account and wider financing channels for OFDI are required. For instance, the establishment of Asian Infrastructure Investment Bank which is designed to provide financial facility to promote large infrastructure projects in this area would bring more investment opportunities. We believe that our results have some implications for the developing countries' FDI theory and policy.We will further study Chinese firms' OFDI behavior from industry level and firm level in our future agenda.

Acknowledgments This article is supported by the National Natural Science Foundation of China (71072066, 71302183), the Sichuan Provincial Science Fund (2015ZR0106; 2016ZR0017). The usual disclaimer applies.

Appendix

See Tables 60.4 and 60.5.

Table 60.4 List of 34 countries

No.	Country name	No.	Country name	No.	Country name	No.	Country name
1	Afghanistan	10	Iraq	19	Sri Lanka	28	Korea, Dem. Rep
2	United Arab Emirates	11	Israel	20	Macao SAR	29	Qatar
3	Azerbaijan	12	Jordan	21	Hong Kong, China	30	Saudi Arabia
4	Brunei	13	Kazakhstan	22	Myanmar	31	Thailand
5	Darussalam	14	Cambodia	23	Malaysia	32	Vietnam
6	Indonesia	15	Korea, Rep	24	Oman	33	Turkey
7	India	16	Lao PDR	25	Pakistan	34	Uzbekistan
8	Iran	17	Liberia	26	Kyrgyzstan		
9	Islamic Rep	18	Libya	27	Turkmenistan		

Table 60.5 Variables and indicators incorporated into the International Country Risk Guide (ICRG) index

PE indicators	Weight (%)
Government stability	12
Socioeconomic conditions	12
Investment profile	12
Internal conflict	12
External conflict	12
Corruption	6
Military in politics	6
Religion in Politics	6
Law and Order	6
Ethic tensions	6
Democratic accountability	6
Bureaucracy quality	4

References

1. Amighini A, Rabellotti R, Sanfilippo M (2013) China's outward FDI: an industry-level analysis of host-country determinants. Frontier Econ China 8(3):309–336
2. Arellano M, Bond S (1991) Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. Rev Econ Stud 58(2):277–297
3. Arellano M, Bover O (1995) Another look at the instrumental variable estimation of error-components models. J Econom 68(1):29–51
4. Buckley PJ, Clegg LJ et al (2007) The determinants of chinese outward foreign direct investment. J Int Bus Stud 38(4):499–518
5. Campa JM (1993) Entry by foreign firms in the united states under exchange rate uncertainty. Rev Econ Stat 75(4):614–622
6. Cushman DO (1985) Real exchange rate risk, expectations, and the level of direct investment. Rev Econ Stat 67(2):297–308

7. Deseatnicov I, Akiba H et al (2013) Reconsideration of the effects of political factors on FDI: evidence from Japanese outward FDI. Rev Econ Financ, Better Adv Press, Can 3:35–48
8. Dixit A (1989) Entry and exit decisions under uncertainty. J Polit Econ 97(3):620–638
9. Dixit AK, Pindyck RS (1994) Investment under uncertainty. Princeton University Press, Princeton
10. Holtz-Eakin D, Newey W, Rosen HS (1988) Estimating vector autoregressions with panel data. Econom: J Econom Soc 56(6):1371–1395
11. Hu B, Tu CL (2012) RMB exchange rate and Chinese outward foreign investment-a cross-country panel analysis. Contemp Econ Res 11:77–78 (in Chinese)
12. Jin W, Zang Q (2013) Impact of change in exchange rate on foreign direct investment: Evidence from China. Lingnan J Bank, Financ Econ 4(1):1
13. Kolstad I, Wiig A (2012) What determines chinese outward FDI? J World Bus 47(1):26–34
14. Li C, Liu HY, Jiang Y (2015) Exchange rate risk, political environment and Chinese FDI in emerging economies: a panel data analysis. Econ World 3(10):145–155 (in Chinese)
15. Liu HX (2006) Chinese overseas investment risk and prevention study. Cent Univ Financ 3:63–67
16. Rivoli P, Salorio E (1996) Foreign direct investment and investment under uncertainty. J Int Bus Stud 27(2):335–357
17. Sahoo P (2006) Foreign direct investment in South Asia: policy, trends, impact and determinants. Asian Development Bank Institute (ADBI), Tokyo
18. Takagi S, Shi Z (2011) Exchange rate movements and foreign direct investment (FDI): Japanese investment in Asia, 1987–2008. Japan World Econ 23(4):265–272
19. Xia LK (2013) How RMB exchange rate affects Chinese firms to invest abroad?-a var model analysis. J NingBo Univ 3:105–110 (in Chinese)
20. Yue LH, Qiang J, Kai TY (2015) Determination of renminbi equilibrium exchange rate, misalignment, and official intervention. Emerg Mark Financ Trade 51:1–14

Chapter 61
An Analysis of the Impact of Medical Insurance Policies on Treatment Selection Among Kidney Disease Patients via System Dynamics

Wanqing Liu, Xiaoxi Zeng and Liming Yao

Abstract With improvement in people's living conditions, the diseases which residents are diagnosed with are changing. Specifically, kidney disease, diabetes, cardiovascular disease, cancer and other chronic non-communicable diseases become the principal diseases impairing individual health. The cost gap is huge between different treatments selected by the patients with advanced kidney disease. The medical insurance affects the patient's choice of treatment, which, in turn, impacts the efficacy of treatment. By utilizing system dynamic, this article, hence, examines how medical insurance influences an individual's choices of treatment in the hope that more reasonable medical insurance policies may be made for kidney disease patients. First of all, the paper, using the flow chart of system dynamics, describes directionally the relationship between medical insurance and the choice of treatment among kidney disease patients. Then, it proceeds to quantitatively address this problem by employing system dynamics simulation model. The paper, eventually, inspects and corrects the model using the data of Sichuan province, providing a reasonable health policy for kidney disease patients.

Keywords Kidney disease · The choice of treatment style · System dynamics · Medical insurance

---

W. Liu
Business School, Sichuan University, Chengdu 610064, People's Republic of China

X. Zeng
Department of Nephrology, West China Hospital, Sichuan University, Chengdu 610064, People's Republic of China

L. Yao (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: lmyao@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_61

61.1 Introduction

Chronic kidney disease is a serious public health issue all over the world. It has been cited on many occasions that problems during treatment of kidney failure are constantly troubling the USA on account of poor outcomes and high costs. Dialysis and transplantation are the most common treatments for individuals with kidney failure. In recent years, the number of end-stage renal disease (ESRD) patients is growing at the rate of more than 7 % a year. In 2009, "the Central Committee of the Communist Party of the opinions of the State Council on deepening the reform of medical health system", clearly put forward basic implementation standards of all medical insurance for urban workers and residents, and the new cooperative medical insurance rates for rural workers and residents are above 90 %. In 2012, China becomes one of the countries with universal coverage health care systems at the rate of 96 %. Enhancing the fairness of health services utilization among Chinese citizens, considered as the principal objective of establishing universal health care, is conducive to reducing catastrophic health expenditure as well as to providing high-quality, effective, and efficient medical services.

By quickly surveying past scholarship on this subject, the paper finds that, firstly, both Chinese and foreign scholars have intensively researched the choices of treatment among kidney disease patients by analyzing influencing factors and treatment effects, while few approach this issue from the perspective of medical insurance. The typical examples are "Management of Chronic Kidney Disease in China Calls for The Implementation of Expert Patient Program with Traditional Chinese Medical Interventions" written by Wu [**?**], "Prevalence of chronic kidney disease in the United States" written by DE Weiner [1], and "Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization" written by GE Chertow [3]. Secondly, in terms of research methods, the scholars largely adopt three kinds of approaches to investigate kidney disease, namely the statistical method, comparison and contrast, and theoretical analysis. But none of them study the problems of kidney disease by using the method of system dynamics. Medical insurance, as a matter of fact, has considerable effect on the choice of treatment style. Accordingly, it is of great importance to explore the effect of medical insurance on the choice of treatment among patients with kidney disease, since the better the treatment, the relative higher the cost, and kidney disease patients, to a certain extent, choose treatment according to their own type of medical treatment insurance. Appropriately enhancing medical insurance enables patients to choose more suitable treatment, achieving better treatment effect. Meanwhile, changing medical insurance policies is conducive to reducing the limiting factors for treatment choices, lowering the incidence of post-operative complications.

There are three kinds of treatment available for patients with advanced kidney disease to choose, namely peritoneal dialysis, hemodialysis and other treatments, each of which differs from another in terms of treatment cost and treatment effect. In order to lower treatment cost and enhance its effect, the paper studies how medical insurance impacts on kidney disease patients' selection of treatment, assisting the government to make more reasonable medical insurance policies for these patients.

System dynamics, a discipline of analyzing and studying information feedback system, establishes a system of microscopic structure and a structure model, which utilizes flow charts and equations to describe the logical and quantitative relationship between system elements, respectively, and uses special simulation software to conduct simulation analysis. It is suitable to apply system dynamics to examining the impact of different medical insurances on patients with kidney disease.

The structure of this paper is as follows: Firstly, it briefly reviews past academic research into kidney disease, seeking to discover the significance of such research. Secondly, it, in Sect. 61.2, largely examines the difference between peritoneal dialysis and hemodialysis and then proceeds to investigate directionally the relationship between medical insurance and patients' choice of treatment, using the flow chart of system dynamics. Thirdly, the paper presents mathematical formula for the model in Sect. 61.3 and conducts a case study in Sect. 61.4, respectively. It, ultimately, draws broad conclusions on the subject.

61.2 Problem Description

Advanced kidney disease is an irreversible chronic disease. No obvious discomfort can be found in the early stages of such disease, but with progressive decline in renal function, further accumulated toxins in the body can cause the symptoms of uremia, such as nausea, vomiting, stomachache, poor appetite, itchy skin, ammonia smell, edema, etc., and cause anemia as well as a series of complications. Hemodialysis, considered as a basic treatment, is unique in pathology and treatment effect and is able to remedy some of the changes in bodily functions. When the kidneys can no longer function adequately, peritoneal dialysis can be an efficient way to purify the blood away from the waste products. Peritoneal dialysis, using the body's own peritoneum as a dialysis membrane, has its inherent limitations. More precisely, the service life of peritoneal dialysis is much shorter than that of hemodialysis, for the peritoneum is a biofilm with a certain life span. Peritoneal dialysis can be implemented at home, at work or during traveling. Patients are able to use fewer medications and to follow a less restrictive diet than they do with hemodialysis. Peritoneal dialysis, hence, is much cheaper than Hemodialysis and is more suitable for patients from low-income families. Nonetheless, reimbursement ratio of medical insurance has a greater impact on patients regarding choosing which kind of treatment. Studying the relationship between these two aspects by utilizing system dynamics enables people to predict an appropriate reimbursement ratio.

Elements, such as medical insurance plans, kidney disease patients' choices of treatment, treatment effect, and the poverty rate, interweave, interacting with each other. This complex system, by using system dynamics, can be divided into several subsystems, and system simulation, which is based on the entire system, can provide the basis for making reasonable medical insurance policies.

Based on the pattern of vicious competition is established the traditional system. The government seems to save an increasingly large sum of money if it provides a lower-level medical insurance service. In this case, however, patients have to choose a cheaper treatment plan, the side effects of which are more severe. As a result, the government expenditure is much higher, revealing that the government loses more budget and that its citizens' life condition is not enhanced.

61.3 The Analysis Model

It is apparent from the diagram that efficacy of treatment is the key factor in terms of addressing the issue of medical insurance policy and patients' treatment plans which, in turn, plays a vital role in assessing the treatment effect. If patients choose more expensive hemodialysis treatment, the therapeutic effect will be better, lowering the incidence of complications. Given the high cost of hemodialysis, patients' choice is affected by the medical insurance policy and family economic conditions (Household finances). Provided that health insurance reimbursement is higher, patients tend to select the high-quality treatment, thereby gaining better treatment effect and avoiding unnecessary side-effects. Accordingly, the follow-up medical expenditure will become much lower, which, in the long run, may help to alleviate the financial pressure of both patients and the society (Fig. 61.1).

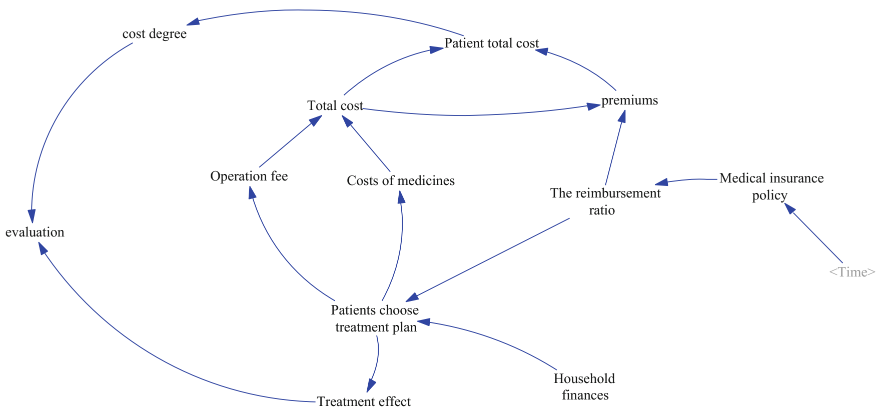


Fig. 61.1 System dynamics model

61.4 Mathematical Model

$$
\begin{aligned}
&\text{Premiums} = \text{Total cost} \times \text{The reimbursement ratio,}\\
&\text{Total cost} = \text{Costs of medicines} + \text{Operation fee,}\\
&\text{Patient total cost} = \text{Total cost-premiums,}\\
&\text{Patients choose treatment plan} = \text{IF THEN ELSE((Household finances} \times 0.6\\
&\qquad\qquad + \text{The reimbursement ratio)} \geq 1.5, 1, \text{IF THEN ELSE}\\
&\qquad\qquad \text{((Household finances} \times 0.6 + \text{The reimbursement ratio)}\\
&\qquad\qquad \geq 1.3, 2, 3)),\\
&\text{Evaluation} = \text{cost degree} + \text{Treatment effect.}
\end{aligned}
$$

61.5 Case Study

There are approximately 7,000 kidney disease patients in Sichuan province where the largest and most advanced hospital is the West China Hospital with multiple cases of kidney disease. According to the data gathered from the West China Hospital from 2005 to 2015, 39 % of the patients enjoy a high income, 46 % are middle income earners, whereas 15 % belong to the low income group. If the reimbursement ratio of medical insurance is low, a great number of individuals with kidney disease tend to choose a cheaper treatment which might not suitable to them. By contrast, provided that the reimbursement ratio is raised, the patients are able to select an appropriate treatment with better effect and lower incidence of complications. The cost, in the long run, is reduced, and the government's fiscal pressure is alleviated. Overall, raising the reimbursement ratio of medical insurance enables patients to choose a suitable treatment, achieving better treatment effect.

For the household finance = 1:

Figure 61.2 illustrates that with the increase of reimbursement ratio, the curve of patients' evaluation, in general, declines, suggesting a better result, even if they are constrained by their financial conditions. Evaluation refers to a comprehensive assessment of treatment cost and its effect. In terms of costs, the lower, the better, whereas for treatment effect, the more effective, the better. In this study the treatment effect is divided into three categories: the number "1" represents the most effective treatment; "2" denotes a more effective treatment; and "3" expresses that the treatment effect is average. In this regard, a downward trend of the evaluation curve demonstrates a better treatment effect at a low cost. Although the year 2008, according to the chart, witnessed a moderate increase in the evaluation, revealing that the cost of treatment was relatively higher compared to that in 2006. Nevertheless, raising the reimbursement ratio enables impoverished individuals with kidney disease to get access to more suitable treatment, obtaining better treatment effect.

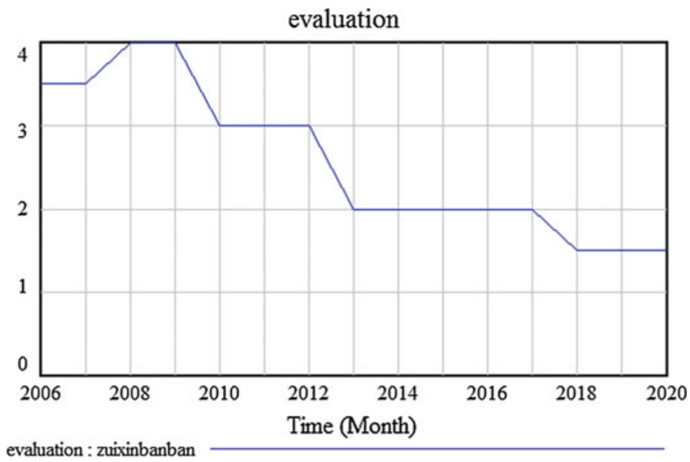


Fig. 61.2 The curve of evaluation of patients with financial difficulty

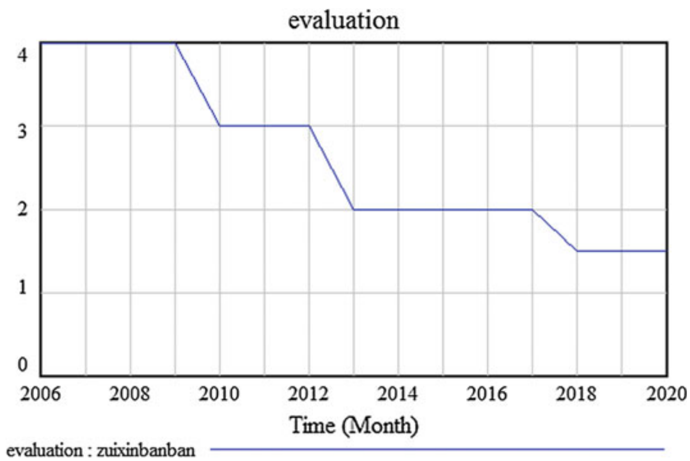


Fig. 61.3 The curve of evaluation of average patients

For the household finance = 2:

It is manifest from Fig. 61.3 that in terms of average Chinese families, the curve of patients' overall evaluation descends as the reimbursement ratio of medical insurance is increased. In other words, raising the reimbursement ratio enables ordinary kidney disease patients to select a more suitable treatment, obtaining better treatment effect.

For the household finance = 3:

As shown in Fig. 61.4, given an increase in reimbursement ratio, the period from 2006 to 2020 saw, witness, and is going to predict a falling trend of the curve of rich patients' overall evaluation. It means that raising the reimbursement ratio enables kidney disease patients who enjoy a high income to select a more suitable treatment, obtaining better treatment effect.

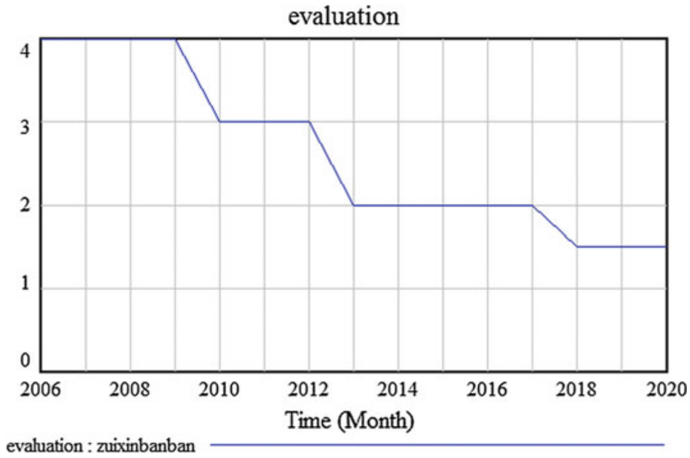


Fig. 61.4 The curve of evaluation of high-income patients

To sum up, if reimbursement ratio of medical insurance is raised, patients, wealthy and disadvantaged alike, are more likely to get access to a better treatment, since their financial pressure is alleviated. More precisely, these patients will obtain more effective treatment, with low incidence of complications and at an affordable cost.

61.6 Conclusion

Kidney disease patients, to a certain extent, choose a treatment according to their own medical insurance. Appropriately raising its reimbursement ratio and enhancing the quality of medical insurance service enable patients to get access to a more suitable treatment, achieving better effect.

Acknowledgments The work is supported by the National Natural Science Foundation of China (Grant No. 71301109), the Western and Frontier Region Project of Humanity and Social Sciences Research, Ministry of Education of China (Grant No. 13XJC630018), the Philosophy and Social Sciences Planning Project of Sichuan province (Grant No. SC12BJ05), and the Initial Funding for Young Teachers of Sichuan University (Grant No. 2013SCU11014).

References

1. Coresh J, Selvin E et al (2007) Prevalence of chronic kidney disease in the united states. Jama 298(17):2038–2047
2. Garrett G, Sardiwal S et al (2013) Pth-a particularly tricky hormone: why measure it at all in kidney patients? Clinl J Am Soc Nephrol 8(2):299–312
3. Stevens LA, Coresh J et al (2006) Assessing kidney functionmeasured and estimated glomerular filtration rate. N Engl J Med 354(23):2473–2483

4. Go AS, Chertow GM et al (2004) Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. N Engl J Med 351(13):1296–1305

Chapter 62
The Bi-Level Optimization Research for Time-Cost-Quality-Environment Trade-Off Scheduling Problem and Its Application to a Construction Project

Huan Zheng

Abstract The project scheduling problems for large-scale construction systems has long been recognized as a critical optimization problem. In this study, a multi-objective programming model is developed for tackling a time-cost-quality-environment trade-off scheduling problem. For solving the multi-objective programming model, a two-stage algorithm is proposed as a combined solution method. In the first stage, the weight-sum procedure is adopted to deal with the multi-objective model, therefore to ensure the validity of conformity in multi-objectives, dividing out the dimensions and unifying the order of magnitude must be performed before the weight-sum procedure; in the second stage, EBS-based GA is developed to solve the problem. Finally, the results and comparisons analysis of a case study are presented to demonstrate the practicality and efficiency of the optimization method.

Keywords Multi-objective · Scheduling problem optimization · EBS-based GA

62.1 Introduction

In recent years, project scheduling has attracted growing attention both from the fields of science and practice because the models are rich in construction project management. Many well-known optimization problems are special cases of the more general project scheduling. In construction system, especially the large-scale one, time, cost and quality are important construction objectives for which significant improvements

H. Zheng (✉)
College of Economics and Management, Southwest University, Chongqing 400715, People's Republic of China
e-mail: 290871340@qq.com

H. Zheng
Chongqing Business Administration Research Center, Chongqing 400067, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_62

have been made during the past twenty years. Some scholars have developed linear programming models to study the tradeoffs among time, cost, and quality [1]. In particular, the issue of environmental impacts are aroused by construction projects, especially eco-environmental impact which may arise during all project phases [2], is the most hot topic that scholars have paid close attention to [3]. The environmental impact of construction project have captured the focuses of project managers all over the world. As such, when a construction project is being planned, its environmental impact should be taken into consideration along with the time [4, 6, 7], cost and quality trade-offs. This leads to a time-cost-quality-environment trade-off problem (TCQETP).

62.2 Mathematical Formulation Model

In this section, a bi-level programming model for the TCQETP is constructed. The mathematical description of the problem is given as follows.

62.2.1 Assumptions

To model the TCQETP for large-scale construction projects in this paper, assumptions are as follows:

(1) The TCQETP consists of a number of activities.
(2) The starting time of each activity is dependent upon the completion of its predecessor.
(3) Capital used by all activities does not exceed limited quantities in any time period, and the total project budget is within deterministic limit.
(4) The quality defect level and environmental impact caused by activities does not exceed limited quantities in any time period.
(5) When an activity is beginning, it cannot be interrupted.
(6) The upper managerial objective is to minimize the total quality defect level and environmental impact, the lower managerial objective is to minimize the total tardiness penalty and the total project time.

62.2.2 Model Formulation

The following notation is used.

j: activity index.
$\overline{T}$: the upper limitation of the total project duration.
t: index of time period.
$\mathrm{Pre}(j)$: set of the immediate predecessors of activity j.
c_j^T: the cost of activity j for unit time.
c_i^P: the total penalty cost of project i for unit time.

t_j^s: the start time of activity j.
t_i^f: the finish time of activity j.
t_i^D: specified project completion time for project i.
t_j^{EF}: the early start time of activity j.
t_j^{LF}: the latest time of activity j.
d_j: the duration of activity j.
d_i: the duration of project i.
q_j: the quality defect level of activity in practice.
q_j^{worst}: the worst limitation quality defect level of activity j.
q_j^{best}: the best limitation quality defect level of activity j.
d_j^{worst}: the duration for the worst limitation quality defect level of activity j.
q_j^{best}: the duration for the best limitation quality defect level of activity j.
w_{jq}: the weight of activity j in quality.
w_{je}: the weight of activity j in environment.
e_j: the environmental impact of activity j.
l_q: the limitation for quality defect defect level in any time period.
l_e: the limitation for environmental impact in any time period.
T_i: the total duration for project i.
Q: the total quality defect level for project i.
E: the total environmental impact for project i.

Decision variables

$$x_{jt} = \begin{cases} 1, & \text{activity } j \text{ finish in time } t, \\ 0, & \text{otherwise.} \end{cases}$$

(1) Lower Level Model

Firstly, the lower level is discussed. When the mathematical description for the lower level is founded, it is easier to determine the mathematical description for the upper level.

① Objective functions for the lower level

For the lower level of the bi-level programming model, firstly, the objective is to measure and minimize the total cost of multiple projects, a mathematical formulation of the objective as follows:

$$\min C^T = \sum^{J} c_j^T d_j. \tag{62.1}$$

Secondly, the lower objective function is to measure and minimize the total penalty of multiple projects, we develop a mathematical formulation of the objective as follows:

$$\min C^p = c_p(t_J^f - t^D). \tag{62.2}$$

Thirdly, the objective is to minimize the total project time, that is the sum of the completion time for all sub-projects,

$$\min T = t_J^f - t_J^f, (o \in \mathrm{Pre}). \tag{62.3}$$

② Constraints of the lower level

There are 4 kinds of constraints on the lower level, details of them are explained in the following.

Precedence constraint:

The start time of each activity is dependent upon the completion of some other activities (precedence constraints of activities). After finishing a specific activity, the next activity must be also started in a project, therefore, we use the constraint:

$$d_j \leq t_J^f - t_l^f. \tag{62.4}$$

Cash flow constraint:

It is also basic and important for project to limit the capital in per time period used by the project.

$$\sum l_{jc} \leq b_c. \tag{62.5}$$

(2) Upper Level Model

After the mathematical description of the lower level model is given, the objective function and constraints of the upper level can now be determined.

① Objective functions for the upper level

For the upper level of the bi-level programming model, firstly, the objective is to measure and minimize the total cost of multiple projects, a mathematical formulation of the objective as follows.

Firstly, the objective is to to measure and minimize the total quality defect level.

$$\min Q = \sum_{j=1}^{J} w_{jq} \left[q_j^{\mathrm{best}} - \frac{q_j^{\mathrm{best}} - q_j^{\mathrm{worst}}}{d_j^{\mathrm{best}} - d_j^{\mathrm{worst}}} (t_j^s + d_j - t_j^{EF}) \right]. \tag{62.6}$$

Secondly, the objective is to to measure and minimize the total environmental impact.

$$\min E = \sum_{I=1}^{I} w_{ije} \sum_{J=1}^{J} \frac{e_{ij}}{d_{ij}} \sum_{t=t_{ij}^{LF}}^{t_{ij}^{LF}} x_{jt}. \tag{62.7}$$

② Constraints of the upper level

The start time of each activity is dependent upon the completion of some other activities (precedence constraints of activities).

$$d \leq t_J^f - t_J^f. \tag{62.8}$$

It is important for project to limit the quality defect level in per time period used by the project.

$$w_q \sum_{J=1}^{J} \frac{q_j}{d_j} \sum_{s=t}^{t+d_{ij}-1} x_{js} \leq l_q. \tag{62.9}$$

It is important for project to limit the environmental impact in per time period used by the project.

$$w_\varepsilon \sum_{J=1}^{J} \frac{e_j}{d_j} \sum_{s=t}^{t+d_{ij}-1} x_{js} \leq l. \tag{62.10}$$

It is also basic and important for project to limit the total capital.

$$\sum_{J=1}^{J} c_j^T \sum_{t=t_{ij}^{LF}}^{t_{ij}^{LF}} \leq B. \tag{62.11}$$

62.3 Solution Approach

Firstly, an interactive fuzzy programming technique is applied to convert the problem from a bi-level programming to a single-level problem. Secondly, an EBS-based GA is introduced to compute the complex non-linear programming problem generated by the first step.

62.3.1 Interactive Fuzzy Programming

In order to handle the above bi-level model, an interactive fuzzy programming technique [5, 8] is applied, as the upper level makes decisions by taking into account not only its own satisfaction but also the satisfaction of the lower level.

The upper level decision maker initially specifies the preferred values (i.e., the lower limit of satisfactory degree) based on certain decision variables and goals before those of the lower level decision makers. This information (i.e., the satisfactory degree of the upper level decision maker should not be less than the lower limit) is modeled by the membership functions of fuzzy set theory and passed to the lower level decision makers as additional constraints or as upper level requirements. The lower level decision makers should not only optimize their objectives but also try to satisfy the upper level decision makers goals and preferences as much as possible.

Here, this paper assume that the upper level and the lower level have fuzzy goals such as the goal should be more than or equal to a certain value using fuzzy theory for their objective functions [5]. Then, through communication with decision makers, the fuzzy goals are quantified by eliciting the corresponding membership functions, so a linear membership function of the fuzzy goal is employed with parameters determined using Zimmermann [8].

62.3.2 EBS-Based GA

Though the technological process of EBS-based GA is roughly similar to the standard GA, there are inherent differences, particularly in the representation, selection, the crossover and the mutation, and is therefore appropriate for solving the problem. The EBS-based GA also sets a two stop criteria in the termination, which means that the iteration will stop when either of the two criteria is met. This two stop criteria is: (1) The iteration reaches the max generation set; (2) If there is no improvement in fitness value in the past cumulative generations.

62.4 A Case Study

62.4.1 Presentation of Case Problem

A large-scale project example is analyzed to illustrate the use of the present model and demonstrate its capabilities. The detailed corresponding data for each activity in sub-project are shown in Table 62.1.

Other relevant data are as follows: the cost, quality defect level and environmental impact is 6 (units: million RMB), 0.06 and 0.07 units for each time period.

Table 62.1 Detailed information of each activity

p_i	Suc(i)	t_i^D	c_i^p	P_i	$Suc(i)$	t_i^D	c_i^p
s	1, 2	0	0	P_5	7	35	10
P_1	3, 4	20	10	P_6	8	30	10
P_2	3, 4, 5	25	10	P_7	8, T	35	10
P_3	6	30	10	P_8	T	30	10
P_4	6, 7	25	10				

62.4.2 Result of Case Problem

The circumstance of the computation for the problem is set as follows: based on the above model, the proposed flc-hGA, is programmed using Visual C++ language and run on a Pentium 4, 2.40 GHz clock pulse with 1024 MB memory. The detailed results are shown below.

The optimal schedule:

$$S = \{(1,2,3,4,5,6,7,8,9,10),(2,1,4,3,5,7,8,6,9,10),(1,5,3,2,4,76,8,10,9),\\ (1,2,4,5,8,3,7,10,6,9),(1,3,2,4,6,5,7,8,9,10),(4,2,3,5,7,1,6,10,9,8),\\ (1,2,4,5,8,3,7,10,6,9),(1,3,2,4,6,5,7,8,9,10)\}.$$

Total quality defect:

$$\sum_{i=1}^{I}\sum_{J=1}^{J} w_{ijq}q_{ij} = 7.77.$$

Total environmental impact:

$$\sum_{I=1}^{I} w_{ije}\sum_{J=1}^{J}\frac{e_{ij}}{d_{ij}}\sum_{t=t_{ij}^{LF}}^{t_{ij}^{LF}} x_{jt} = 8.85.$$

The sum of the completion times for all sub-project:

$$\sum_i T_i = P_2(24) + P_1(18) + P_3(34) + P_4(28) + P_5(39)\\ + P_6(27) + P_7(31) + P_8(28) = 229.$$

Total penalty cost:

$$\sum_i c_i^p = -10.$$

Total cost:

$$\sum_i c_i^T = \sum_{i=1}^{I}\sum_{j=1}^{J} E(\widetilde{c}_{ij}^T)E(\widetilde{d}_{ij}) = 860.$$

Table 62.2 Comparison results among hGA, a-hGA and flc-hGA

Pop-size	Max-gen	hGA		a-hGA		EBS-based GA	
		Computing time (s)	Convergence iteration number	Computing time (s)	Convergence iteration number	Computing time (s)	Convergence iteration number
20	200	15.6	96	15.5	94	14.7	90
50	300	40.2	83	36.3	79	30.4	75
100	400	94.4	79	70.5	75	55.2	70
200	500	198.1	77	156.5	72	11.2	68

62.4.3 Algorithm Evaluation

There are many viable algorithms to solve such a project decision problem. To demonstrate the effectiveness and efficiency of the flc-hGA, the proposed flc-hGA is compared with heuristic algorithms from the preceding project examples, i.e., the hybrid genetic algorithm (hGA), and the EBS-based GA. To conduct the comparisons in a similar environment, all three algorithms were programmed using the same Visual C++ language, and the rate of crossover and mutation were 0.5 and 0.4, respectively. The performance of the three algorithms is shown in Table 62.2.

62.5 Conclusions

In this paper, a multiple objective trade-off problem for large-scale construction projects is proposed for dealing with project scheduling while minimizing the total project duration, project penalty cost, cost, quality defect level and the environmental impact. The main advantage of the proposed method is that it provides a systematic workable method for the decision-making process. In order to solve the problem, a EBS-based GA is developed to enhance the optimization quality and stability. Finally, a project is used as a practical example to demonstrate the practicality and efficiency of the model. The area for future research has three aspects: firstly, investigate uncertainties, such as fuzzy or random systems to handle the model more reasonably and effectively. Secondly, more complex practical problems such as more dimensions scheduling should be considered. Thirdly, more efficient heuristic methods to solve these NP hard problems with more constraints could be developed. Each of these areas is very important and equally worthy of attention. A detailed analysis and further research are necessary to reveal more properties for solving these problem.

Acknowledgments This work was supported by the Project of the Key Research Base of Philosophy and Social Sciences in Sichuan Province (Xq15C12).

References

1. Babu AJG, Suresh N (1996) Project management with time, cost, and quality considerations. Eur J Oper 88(2):320–327
2. Brismar A (2004) Attention to impact pathways in EISs of large dam projects. Environ Impact Assess Rev 24(1):59–87
3. Chen S, Chen B, Su M (2010) The cumulative effects of dam project on river ecosystem based on multi-scale ecological network analysis. Procedi Environ Sci 5:12–17
4. Ke H, Ma JJ (2014) Modeling project time-cost trade-off in fuzzy random environment. Appl Soft Comput 19:80–85
5. Lee ES, Shih HS (2001) Fuzzy and multi-level decision making: an interactive computation approach. Springer, London
6. Monghasemi S, Nikoo M et al (2015) A novel multi criteria decision making model for optimizing time-cost-quality trade-off problems in construction projects. Expert Syst Appl 42(6):3089–3104
7. Xu J, Zheng H et al (2012) Discrete time-cost-environment trade-off problem for large-scale construction systems with multiple modes under fuzzy uncertainty and its application to Jinping-II hydroelectric project. Int J Proj Manag 30:950–966
8. Zimmermann HJ (1978) Fuzzy programming and linear programming with several objective functions. Fuzzy Set Syst 1(1):45–55

Chapter 63
Impact Analysis of Urbanization for Chinese Energy Consumption Based on Panel Data of Chinese Provinces

Chao Wang and Liping Fu

Abstract This paper uses the IPAT model and the panel data of 30 provinces from 1997 to 2012 to study the effect of urbanization on Chinese energy consumption, and the result shows that the effect is positive, which of the elasticity coefficient is 0.2. It tests that urbanization has obvious "positive effect" on energy consumption, which mainly embodies the energy consumption on traffic, commodity consumption, daily life and construction (including residents housing), etc. will increase substantially in the process of urbanization. Based on the above research, the author put forward some suggestions, including decreasing the construction waste, enhancing the city plan and management level, and guiding the residents' consumption to upgrade.

Keywords Urbanization · Energy consumption · Positive effect

63.1 Derivation of the Problem

Urbanization does not only mean the migration of population, but also means the change of their life style, pattern of consumption and area of employment. Although urbanization could stimulate domestic demand and economic growth, at the same time cause the shortage of energy, environmental pollution, traffic jam and many other negative influences. Because there are many factors impact energy consumption and the mechanism of action is comparatively complex, it has strongly realistic significance to analog the consumption function during the urbanization, and then accurately analyze the elastic coefficient of energy consumption impacted by urbanization to study the influence mechanism of urbanization impacting energy consumption by using empirical analysis.

C. Wang (✉)
Economics School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 20075726@qq.com

L. Fu
Institute of Industrial Accounting School of Finance, Lanzhou 730050,
People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_63

Jones [8] found that urbanization created the benefits by scale economy, also caused the increase of transportation energy consumption and the energy consumption per unit output. He concluded the correlation was positive between urbanization and per capita energy consumption. Parikh and Shukla [25], York et al. [32], Liu [16], Hossain and Zarzoso [7] and many other researchers also got the same result about this positive correlation. Al-mulali et al. [1] focused on the correlation between urbanization and per capita energy consumption among different nations. Mohammadi and Amin [22] suggested the existence of long-run relation between energy (electricity) consumption and output in high and low-growth panels but its absence in the panel with negative growth by test of cointegration. Nasr [23] indicated that policies should be aimed at promoting energy efficiency to reduce emissions without sacrificing growth in South Africa. Roy and Yasar [28] found that exporting to reduce the use of fuels (relative to electricity) and concerns over endogeneity of exporting status to be relevant by utilizing data from Indonesia. Refahi and Talkhabi [26] demonstrated that using green roof in Very Hot Dry (Bandar Abbas), Warm Dry (Isfahan), and Mixed Dry (Tabriz) climates caused energy consumption to decrease by approximately 8.5, 9.2 and 6.6 %, respectively. In addition, Esseghir [4] studied the relationship between energy consumption and economic growth in the objective of sustainable development. However, the study of Lariviere and Lafrance [10] indicated the higher urbanization level area had lower per capita energy consumption in Canada.

Other scholars studied on China's energy consumption. Liu et al. [17] researched the dynamic relation between the energy intensity and urbanization in China, and the result indicated there was a nonlinear causal relationship between Chinese energy intensity and urbanization. Cheng [2], Zhang [24], Ma [6] and some other researchers' studies shown urbanization would increase the energy consumption in China. Sun [30] indicated that China's growing energy demand was driven by urbanization, and household energy consumption patterns, which were characterized by effects of "path lock-in", had long-term impacts on China's energy demand. Lin [14] identified and quantified the driving forces of changes of energy intensity across China's provinces between 2005 and 2010, and results showed that technological change and capital-energy substitution were the major drivers of the declining energy intensity. Su [29] indicated that industry structures and energy efficiencies were the major factors influencing regional CO_2 emission intensities, and more attention should be paid to prevent the CO_2 emissions per energy consumption (PECE) of under developed cities or provinces from increasing rapidly rather than only focusing on reducing the PECE of developed region. Zhao [34] indicated that technology progress, energy price and economic development have positive influence on TFEE (total-factor energy efficiency), and the impact of technology progress is found to be of the most significance. Ma and Liu [20] developed a series of formulations to calculate both embodied and operating energy based on hybrid energy input-output model. Taking 2011–2050 as the study period, and combined the embodied and operating energy and designed six scenarios to comprehensively quantify the impacts of three factors: new building floor areas, energy efficiency standards and its implementation rate on the energy saving potential. And then they indicated that energy saving technology development and more emphasis on key areas will reduce building energy consumption significantly in the short term, while household lifestyle changes, as well as improved building energy efficiency, should be given a higher priority in the long run. Liu [19] extended the KAYA identity with price and expenditure factors and then applies the LMDI method to a decomposition of residential energy consumption in China from 1993 to 2011, and suggested further marketization and deregulation of energy prices, the promotion of advanced energy types and guidance for better energy consumption patterns. Liu and Zhou [18] used an extended STIRPAT model to investigate the effects of human activity on energy consumption and three types of industrial pollutant emissions (exhaust gases, waste water and solid waste) at the national and regional levels and tested the environmental Kuznets curve (EKC) hypothesis. Ren [27] indicated that in 2015 and 2020, the total primary energy consumption will be 1.57 and 1.85 times higher than that of in 2009, and the carbon emissions are estimated to be 1.48 and 1.67 times respectively in Shandong.

This thesis will study the correlation between urbanization and energy consumption in China by using empirical research method based on macroeconomic data. As well, I will consult some microeconomic evaluation method as a reference to analyze the effect of urbanization to energy consumption in China from family level.

63.2 The Empirical Test of the Urbanization's Effect on China's Energy Consumption

63.2.1 The Selection of Model and Data

This research selected the improved IPAT Model by Dietz and Rosa [3], namely, STIRPAT Model, as

$$I = aP_i^b A_i^c T_i^d, \tag{63.1}$$

where, b, c, d represents the influence elasticity of itself respectively, T represents the comprehensive structured elements, excepts for the population and wealth, driven by the technology progress. After the variation of taking logarithm, we can use the mode to conduct the regression estimation and test:

$$\begin{aligned} Ln(en_{it}) = & a_0 + a_1 \ln(\text{Pop}_{it}) + a_2 \ln(A_{it}) + a_3 \ln(\text{Ind}_{it}) + a_4 \ln(\text{Sav} - it) \\ & + a_5 \ln(\text{Urb}_{it}) + u_{it}, \end{aligned} \tag{63.2}$$

where, 'en' stands for the volume dose of the energy consumption, "Pop" stands for the total population in the year-end, 'A' represents GDP per capita which stands for the affluence, 'Ind' represents the proportion of the secondary industry in the entire GDP, and 'Sav' represents the proportion of the tertiary industry in the entire GDP, 'Urb' stands for the proportion of the urban population in the total population.

a_1, a_2, a_3, a_4, a_5 are the model estimate parameters reflecting the effect degree of variation in each variable to the energy consumption, a_0, u is the constant term, stochastic disturbance term, respectively. In order to ensure the accuracy of the model estimate, this research selects the provincial panel data to carry out the empirical research, in a period from 1997 to 2012. Besides, the data is selected from the China Statistical Yearbook as well as the China Energy Statistical Yearbook over the years.

63.2.2 The Regression Estimate and Test of the Model

Considering that the selected panel data is the typical short panel, and cross section is not drawn randomly from a larger sample, the author deems the Fixed Effect Model (FEM) is appropriate in this case. Therefore, this research chooses FEM and uses EViews 6.0 to run the estimate (Tables 63.1, 63.2 and 63.3).

Table 63.1 Regression coefficient

Variable	Coefficient	Std. error	t-statistic	Probability
C	−2.104385	0.570919	−3.68596	0.0003
log(POP)	0.862669	0.085308	10.1124	0
log(A)	0.562532	0.028325	19.85972	0
log(IND)	0.505187	0.080907	6.244003	0

Table 63.2 Model of overall significance

Weighted statistics			
R-squared	0.985706	Mean dependent var	8.76601
Adjusted R-squared	0.984614	S.D. dependent variable	0.758665
S.E. of regression	0.094105	Sum squared resid	3.940809
F-statistic	902.5649	Durbin–Watson stat	0.576294
Prob(F-statistic)	0		

Table 63.3 Model of overall significance

	Urban	Rural
Wash machine	98.02	67.22
Refrigerator	98.48	67.32
Air-condition	126.81	25.36
Television	136.07	117
Computer	87.03	21.36

The result of the model estimate shows that, R^2 is 0.985706, adjusted R^2 is 0.98461, F Statistical value is 902.5649, and significant under the significance level of 0.01, which suggests that the model is set reasonably, and the fitting degree is relatively high, which effectively explains the variation of the energy consumption in the process of the urbanization. The regression equation as follows:

$$\begin{aligned}\ln(en_{it}) = & -2.104385 + 0.862669\ln(\mathrm{Pop}_{it}) + 0.562532 ln\ln(A_{it}) + 0.505187\ln(\mathrm{Ind}_{it}) \\ & - 0.040275\ln(\mathrm{Sav} - it) + 0.303104\ln(\mathrm{Urb}_{it}).\end{aligned}$$

We can draw a conclusion from the result of the model estimate:

(1) In the process of Chinese urbanization, the most important factor that affects the energy consumption is the total population, the coefficient is 0.862669, and significant under the significance level of 0.01, which suggests while there is 1 % increase in Chinese population, the energy consumption increases by 0.86 %, indicating that it remains the extended development as the main way in China, and the residents still keep the energy-intensive lifestyle.
(2) The second important factor that affects the energy consumption is the proportion of the secondary industry in the entire GDP, the coefficient is 0.56, and significant under the significance level of 0.01, which suggests while there is 1 % increase in secondary industry proportion, the energy consumption increases by 0.56 %. However, the influence coefficient of the tertiary industry to the energy consumption is negative, and not significant, which means that the impact of the energy conservation and emissions reduction on the development of the tertiary industry is not obvious, probably since the transportation in the tertiary industry grows rapidly, thus offsets the negative effect of the energy consumption from the other service industry.
(3) The influence coefficient of the urbanization to the energy consumption is 0.303104, which is positive, and significant under the significance level of 0.01, which indicates that while there is 1 % increase in Chinese urbanization, the energy consumption increases by 0.3 %.

63.3 Mechanism of Action of the Effect by Urbanization to Energy Consumption of China

During the rapidly urbanization period, China has the steep growth of urban population and cities size. Extended development of the growth of city characteristics is shown in this period in China. Empirical test proved urbanization will increase the energy consumption in China. The Mechanism of action could be found from the following field:

63.3.1 The Transportation Energy Consumption of Chinese Family Would Increase Markedly During the Urbanization

(1) The gap of the transportation energy consumption between urban and rural residents is relatively remarkable. Generally, the rural population living nearby their fields and usually not leaving their village for vacation in slack seasons, long-distance travel are less. Thus, the daily transportation energy consumption is lower. Whereas, the urban population have to pass a long distance by public transportation or car because of working, shopping, amusement and other daily life, which has higher energy consumption than rural population. And the larger of the city scale, the higher transportation energy consumption will be costed. Therefore, the migration of population during urbanization will tremendously increase the energy consumption for people daily trips.

(2) Excessively urban space expanding also would pull the transportation energy consumption higher and higher. 'Land finance' and 'Only GDP' government performance examination standard both will attract the government and officer to focus on expanding the boundary of the city. The blindly and rashly projecting of city space causes the extremely unreasonable spatial distribution. The long distance among business area, living area and shopping area adds the demand of transportation. This not only increases the transportation energy cost, but also wastes the great quantity of energy for infrastructure construction. Moreover, the unreasonable urban expansion exacerbates the traffic jam that causes many city becoming actually blocking city and increases the inefficiency energy cost.

63.3.2 The Change of Commodity Consumption During the Urbanization Will Cause More Energy Consumption

The CONSP of urban residents was 16674 RMB and only 5908 RMB among the rural in 2012. This huge gap means that the migrants from rural to urban will cause the consumption of goods and services increasing markedly, and then increase the energy consumption for producing these products. The data shows that the Engel's coefficient of rural residents is 39.3 % which more than 3.1 % higher than the urban residents'. It means that migration from rural to urban during urbanization could decrease the Engle's coefficient effectively, which means the ratio of the consumption of the products other than foods will rise. According to the passed data, the products other than foods will cost more energy than the food products. Therefore, the decrease of Engle's coefficient must increase the energy consumption obviously. Zhang and Niu [33] calculated the increase of the total energy consumption caused by the change of urban residents' consuming behavior from 2000 to 2007, would rise from 540, 339, 200 TCE (tons of standard coal equivalent) to 645, 387, 100 TCE, at the same

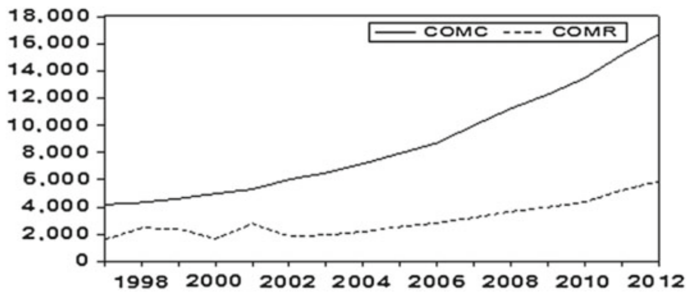


Fig. 63.1 Urban and rural residents' consumption expenditure (COMC: Urban residents' living consumption expenditure, COMR: Rural residents' living consumption)

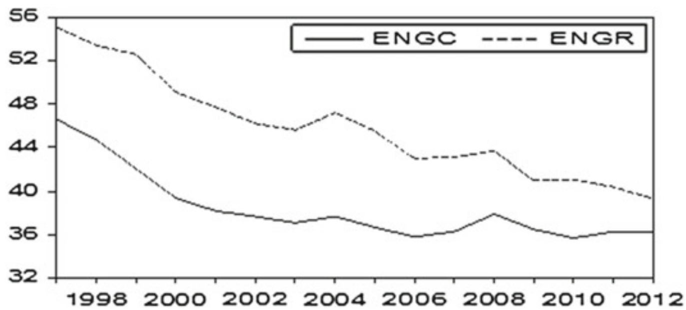


Fig. 63.2 Urban and rural residents' Engle Coefficient

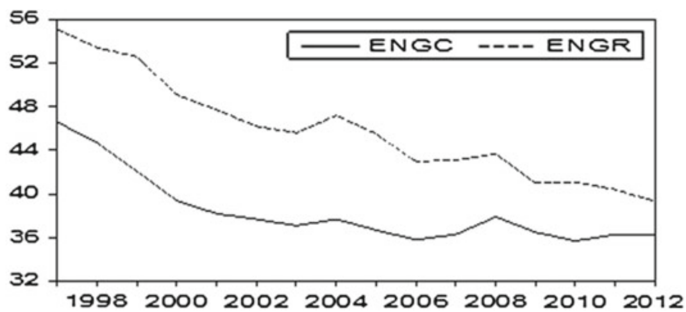


Fig. 63.3 The change of the urban and rural per capita energy consumption

time, the quantity decreased from 196, 091, 300 to 115, 551, 400 TCE in rural. The average cost of standard per person reached 1.087 TCE in city and only 0.159 TCE in rural (Figs. 63.1, 63.2, 63.3).

63.3.3 Urbanization Would Increase the Direct Energy Consumption for Daily Life

Urbanization will change the life style of urban residents, and then increase their energy consumption for daily life. More household electrical appliances must cause more energy cost. In 2012, there were some researches which showed every 100 urban families owned 98.02 washing machines, 98.48 refrigerators and 126.81 air-conditions that was more than 67.22 washing machines, 67.32 refrigerators and 25.36 air-conditions of rural residents. Moreover, the difference of environment, relaxation and life style between city and county makes people using household electrical appliances differently at the application time and frequencies. The more application time and frequencies lead a higher energy consumption in cities. It means urbanization will increase the energy consumption in their daily life as a result of movement from county to city.

63.3.4 The Energy Consumption of Housing Will Be Greatly Enhanced in the Process of Urbanization

The effects for energy consumption by urbanization also come from housing demand of immigrants. Firstly, during the urbanization, immigrants must have rigid demands for houses located in cities. These rigid demands will add energy consumption for building materials and construction. In addition, the building-related industries cost much more energy than others. Thus, the rigid demand for houses because of urbanization is going to make building-related industries developing faster than before, and then causes the great more consumption of energy. Secondly, the requirements for function of urban building are higher, and the decoration is more well-made. Northern cities in China have heating system and almost every parts of Chinese cities' house having air-condition system, so that it would spend much more energy than other countries. Finally, the energy cost of housing in China is higher than other nations. some documents indicate that the energy cost per unit in China is 2–3 times higher than western Europe and North America with the same latitude. And only 15 to 20 % of housing in the new constructions executed architecture saving energy design standard every year.

63.4 Policy Suggestions

The urbanization in China makes the rural residents transfer to the urban areas for living, and also promotes the rapid increase in energy consumption at the same time. The influential mechanism of this promotion action is mainly realized by the following four channels:

(1) With the increase in the demand of the rural residents entering cities on transportation and relevant infrastructure, it drives the increase in energy consumption.
(2) With the increase in the demand of rural residents entering cities on commodities and services, the energy consumption also increases.
(3) The demand of the rural residents entering cities on buildings, the energy consumption also increases.
(4) The energy consumption in the family life of rural residents entering cities directly increases.

By the promotion of the elements including the unreasonable urban planning, unstuck energy price and low-efficient energy subsidy policies and so on, the influence of urbanization on energy consumption becomes more prominent by the above four channels, and expresses as the relatively obvious "positive effects". It makes the influence of urbanization in China on energy consumption relatively more complies with the action mechanism described by "urban environmental change theory". Besides, with the appearance of the problems including traffic jam and low efficiency of infrastructure during the process of urban development etc., the "theory of compacted theory" does not adapt to the realistic bases of current urbanization in China. According to the panel data of 30 provinces in China (except Tibet Autonomous Region) from 1997 to 2012, the empirical research of STIRPAT Model is adopted, and the analysis on the influential action mechanism of urbanization on energy consumption is also verified: urbanization has positive influential relation with energy consumption, and the elasticity coefficient of the influence is 0.2 or so, meaning that every 1 % of increase in urbanization level, the energy consumption in China will be increased by 0.2 %, which makes the conclusions drawn in the research more persuasive and bearing stronger policy connotation. Based on the above research, the author put forward the following suggestions:

(1) Decreasing the construction waste to reduce the energy utilization in the process of the urbanization. On one hand, we must respect the inherent law of the city grow in the urban planning, and make the planning be looking-forward by constructing sustainable developing space structure which adapts to the dynamic change of the city, to reduce large-scale destroy and build' phenomenon and the waste of the city construction in the process of city growing. On the other hand, decreasing the energy loss should be placed as the priority in the process of design and construction of the buildings to avoid the construction waste in that concerning too much with the individuality and image of the building.
(2) Enhancing the city plan and management level to decrease the energy consumption in the city operation. ① energy conservation and emissions reduction and ensuring energy safety should be put in the important place in the city planning by shifting the focus of the city land balance to the carbon-oxygen balance in the city development. ② Developing the living style of 'big region and small family', and carrying out various of community outdoor-activity, which will reduce the daily use of the energy as well as the energy consumption per capita, simultaneously, and boost the service efficiency of the public facilities and buildings.

③ Planning the layout of urban functional areas reasonably, and promoting the mix of the city function so as to decrease the mis-match of 'work-residence-business', and reduce the transportation energy consumption of residents trips in the process of the urbanization. ④ Developing the low energy-cost city transportation system to improve the use intensity of vehicle, and calling for green travel to cut off the energy consumption of transportation.

(3) Guiding the residents' consumption upgrade by the consumption policy. On one hand, the government will use the methods of the consumption credit and fiscal tax, so as to lead the residents transform the consuming style from the basic type to the enjoying type and developing type by encouraging the residents to increase the consumption of the services, such as the electronic communication, education, travelling and entertainment, which, therefore, will drive the industry structure transformation to the low energy, high value-added services. On the other hand, the government should make use of the policy instruments, such as low-carbon product pricing policy, low-carbon consumption subsidy policy and the market-access system of the low-carbon produce, so as to guild the residents to establish the low-carbon consumption concept that uses the low-carbon consumer goods instead of the high energy-cost goods.

References

1. Al-mulali U, Sab CNBC, Fereidouni HG (2012) Exploring the bi-directional long run relationship between urbanization, energy consumption, and carbon dioxide emission. Energy 46(1):156–167
2. Cheng J, Chen J (2009) The regional differences of China's energy consumption in the process of urbanization-empirical research based on panel data. Econ Rev 3:38–46
3. Dietz T, Rosa EA (1997) Effects of population and affluence on CO2 emissions. Proc Natl Acad Sci USA 94:175–179
4. Esseghir A, Khouni LH (2014) Economic growth, energy consumption and sustainable development: the case of the union for the mediterranean countries. Energy 71:218–225
5. Ghosh S, Kanjilal K (2014) Long-term equilibrium relationship between urbanization, energy consumption and economic activity: empirical evidence from India. Energy 66:324–331
6. Heng MA (2012) Influence of urbanization and industrialization on China's energy consumption. China Soft Sci 524–527(1):3122–3128
7. Hossain MS (2011) Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. Energ Policy 39(11):6991–6999
8. Jones DW (1991) How urbanization affects energy-use in developing countries. Energ Policy 19(7):621–630
9. Jun C, Cheng J, Wu Q (2007) The energy consumption and the level of industrialization among regional difference in China. China Popul Resour Environ 17(5):59–64
10. Lariviere I, Lafrance G (1999) Modelling the electricity consumption of cities: effect of urban density. Energ Econ 21(1):53–66
11. Li H, Jf Shi (2014) Energy efficiency analysis on chinese industrial sectors: an improved super-SBM model with undesirable outputs. J Clean Prod 65:97–107
12. Liang ZH (2010) The influencing factors of energy consumption under different stages of urbanization. J Shanghai Univ Financ Econ

13. Lin B (2010) China's energy strategy adjustment under energy conservation and carbon emission constraints. Soc Sci China 31(2):91–110
14. Lin B, Du K (2014) Decomposing energy intensity change: a combination of index decomposition analysis and production-theoretical decomposition analysis. Appl Energ 129:158–165
15. Lin B, Liu X (2010) China's carbon dioxide emissions under the urbanization process: Influence factors and abatement policies. Econ Res J
16. Liu Y (2009) Exploring the relationship between urbanization and energy consumption in China using ARDL (autoregressive distributed LAG) and FDM (factor decomposition model). Energy 34(11):1846–1854
17. Liu Y, Xie Y (2013) Asymmetric adjustment of the dynamic relationship between energy intensity and urbanization in China. Energ Econ 36:43–54
18. Liu Y, Zhou Y, Wu W (2015) Assessing the impact of population, income and technology on energy consumption and industrial pollutant emissions in China. Appl Energ 155:904–917
19. Liu Z, Zhao T (2015) Contribution of price/expenditure factors of residential energy consumption in China from 1993 to 2011: A decomposition analysis. Energ Convers Manag 98:401–410
20. Ma JJ, Liu LQ et al (2015) Exploring the critical factors and appropriate polices for reducing energy consumption of China's urban civil building sector. J Clean Prod 103:446–454
21. Martínez-Zarzoso I, Maruotti A (2011) The impact of urbanization on CO_2 emissions: evidence from developing countries. Ecol Econ 70(7):1344–1353
22. Mohammadi H, Amin MD (2015) Long-run relation and short-run dynamics in energy consumption-output relationship: international evidence from country panels with different growth rates. Energ Econ 52:118–126
23. Nasr AB, Gupta R, Sato JR (2015) Is there an environmental Kuznets curve for South Africa? a co-summability approach using a century of data. Energ Econ 52:136–141
24. Niu S, Zhang X et al (2011) Household energy use and emission reduction effects of energy conversion in Lanzhou City. China Renew Energ 36(5):1431–1436
25. Parikh J, Shukla V (1995) Urbanization, energy use and greenhouse effects in economic development: results from a cross-national study of developing countries. Globa Environ Chang 5(2):87–103
26. Refahi AH, Talkhabi H (2015) Investigating the effective factors on the reduction of energy consumption in residential buildings with green roofs. Renew Energ 80:595–603
27. Ren L, Wang W et al (2015) Analysis of energy consumption and carbon emission during the urbanization of Shandong Province, China. J Clean Prod 103:534–541
28. Roy J, Yasar M (2015) Energy efficiency and exporting: evidence from firm-level data. Energ Econ 52:127–135
29. Su Y, Chen X et al (2014) China's 19-year city-level carbon emissions of energy consumptions, driving forces and regionalized mitigation guidelines. Renew Sustain Energ Rev 35:231–243
30. Sun C, Ouyang X et al (2014) Household pathway selection of energy consumption during urbanization process in China. Energ Convers Manag 84:295C304
31. Yıldırım E, Sukruoglu D, Aslan A (2014) Energy consumption and economic growth in the next 11 countries: the bootstrapped autoregressive metric causality approach. Energ Econ 44:14–21
32. York R, Rosa EA, Dietz T (2003) Footprints on the earth: the environmental consequences of modernity. Am Sociol Rev 68:79–300
33. Zhang X, Niu S (2011) The study on household energy consumption and carbon emissions in china's urbanization. China Soft Sci 9:65–75
34. Zhao X, Yang R, Ma Q (2014) China's total factor energy efficiency of provincial industrial sectors. Energy 65:52–61

Chapter 64
The Research on Functional Mechanism of Earthquake Rumors and Coping Strategy

Huifeng Zhang, Feng Wang, Na Cui and Ziqi Wang

Abstract In the modern environment, with the adoption of flexible disorderly network transmission, the spreading force of the earthquake rumors becomes faster and stronger. Some of the rumors in the transmission often change, which is the memory errors of the receivers and transmitters, which is all the more due to every man's own intentional and unintentional subjective feelings in the process of communication. We also know that the earthquake rumors refer to adopting a variety of communication channels (media) to transfer the information related to things, events and unproven elaborated or interpreted problems that attract the attention of the public. So this paper is aimed at, take earthquake rumors for example referring to the literature and traditional media news reports about the earthquake rumors to understand the process of earthquake rumors, spread audience, media and public managers. Lastly, the problems and countermeasures will be identified and discussed through studying the relevant literature and the authors' personal understandings of rumors in the media under China's media environment.

Keywords Earthquake rumors · Functional mechanism · Social risk · Coping strategy

64.1 Introduction

Rumors can easily induce emergencies, even escalate and trigger panics in society [26]. Earthquake rumors refer to the social rumors with the most public attention, high incidence and big impact, which probably trigger the greatest panics [24]. But rumors can not be eliminated completely either from a society or from an

H. Zhang (✉) · Z. Wang
Institute of Emergency Management and Reconstruction in Post-disaster, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: zhanghf610@gmail.com

F. Wang · N. Cui
Seismological Bureau of Shandong Province, Jinan 250014, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_64

organization. Researches about rumors include work in economics, sociology and psychology, etc. Economists have kept their watchful eyes on rumors both from a theoretical and an empirical point of view, like price and market selection [2]. Sociologists' researches mainly focus on the effects of rumors on management and policymaking. Psychologists' researches attach importance to the role of uncertainty, anxiety, and psychology of rumors. In the fields of journalism and communication, related researches by drawing on the differential equations to figure out the rumors spreading simulation model [18]. Zeccola [23] proposed to minimize the negative social utility of rumors spreading in the control of situation so as to improve the rumors management in emergency and yield positive social utility.

Earthquake rumors are often accompanied by the eruption of earthquake, and develop into secondary disasters [1]. How to cope with the public opinion under the earthquake is another hot orientation of the earthquake disaster risk research, attracting the attention of scholars for decades of years. Wijkman [21] indicated that the emergence of earthquake rumors can be defined as a kind of socio-psychological phenomena. Waizenegger [18] constructed a model of public perception and response to communication about earthquake hazards risk communication programs. Based on the commonality of rumors about earthquake, analyses both audience and mass media in detail [25]. Analysis the attitude, behavior and distinct capability to earthquake rumor, presented the Open Day and opened a new informative channel to implement the interactions with the public, for answering questions and making comments [16]. In response to the earthquake rumors, Seismologists urged calm and told the public not to believe rumors about more earthquakes. But by using mathematical model technology to research in generation, evolution, and diffusion mechanism of earthquake rumors have not been recorded. Especially Longmen Shan fault zone earthquake activity is frequent, bring to China a lot of earthquake rumors, caused great damage [13]. Through literature and network retrieval, 6 samples of earthquake rumors introduced to the earthquake rumors events example table are shown in Table 64.1.

Natural disasters which take place frequently in the world have varying impacts according to the different types including: droughts, earthquakes, floods, hurricanes, landslides, tsunamis, volcanic eruptions, and windstorms, etc. [4]. Thus, there seems to be a general consensus that natural disasters tend to become more severe, experiencing more deaths, greater economic impact, property damages, resource shortages, and social and political impacts [23]. A natural disaster can even challenge the power structure of an affected community, disrupting livelihood strategies and deconstructing social arrangements, resulting in the mass movement of people away from the scene and into inadequate temporary facilities threat to the society [17]. In recent decades, although some scholars, policy makers, and relief organizations suggest that natural disasters bring groups together and dampen conflicts. However, there has been a growing recognition, particularly in affected countries, that the link of natural disasters and social conflict caused by natural disasters does not exist in vacuums, and the interaction between the two creates and perpetuates vulnerabilities that place communities at risk, further entrenching poverty and inequality [2].

Table 64.1 Earthquake rumors events in China

Date	Location	The cause	Influence scope	Refute rumors
11pm, May 21, 2008	Hunan Loudi	The epicenter of Sichuan 5.12 devastating earthquake	Thousands of people migrated to the central square in Loudi; Cell phone lines were jammed; a local university's nightly 10:30pm curfew was largely ignored by the students	The large TV in the square reiterating the TV message
May 19, 2008	Chengdu and Xi'an	A TV-broadcasted message of a probable strong aftershock	Widespread panic in the cities near the epicenter, and along the extension of the seismic fault, of the Wenchuan earthquake among others	The provincial government denied the rumors
Feb 22, 2010	Shanxi Xianyang	A series of earth-quake drills at local hospitals	Tens of thousands of people grabbed prized possessions and fled their houses in the middle of the night following rumors of an imminent earthquake	The provincial government denied the rumors by text message
Apr 22, 2010	Shanxi	Two high school students to increase space hits	Tens of thousands of people grabbed prized possessions and fled their houses in the middle of the night following rumors of an imminent earthquake	Two high school students were being held under administrative detention
May 2, 2010	Hubei Laohekou	Rumors spreaded by mouth to mouth	Tens of thousands of jittery residents sleeping in the street field Laohekou police traced the source rumors	The earthquake department deny the rumors and
Aug 14, 2010	Xiamen, Quanzhou and Zhangzhou	The message "A lot of people go out take refuge" from the BBS	Outgoing farmer returned hometown lead to many plants had closed	Quanzhou seismological bureau immediately reacted to these rumors

64.2 Earthquake Rumors

After the incident, in the face of extremely complicated reality and debated the huge amounts of information, how to implement effective monitoring, will be a huge challenge. This time, if you can introduce government resources to these false information filtering and regulation, at the same time of gain better effect, also can reduce the burden of the mainstream media. At the same time, following a rumor to hit on the incident, will be treated as relevant national laws and regulations as the basis, will be able to rumours and produce greater deterrence tale [26].

Rumours the existence necessity of information society and the audience has to face, rumors because their imaginations and the characteristics of a lack of evidence, the rumor itself is maintaining social stability, so for dealing with rumors the truth of the information itself is to restore the audience [4]. And the media in the dissemination of rumors information to also cannot be avoided, the role of earthquake rumors in incident, mobile phones, the Internet and other media in the rumor produce not only ACTS as a carrier, at the same time also ACTS as a tool in control of rumors.

The influx of information, as well as the audience demand difference, make the medium it hard for their role [18]. As gatekeepers of information transmission in today's information society will encounter various obstacles, their role as gatekeepers is also difficult to achieve, and play. Media due to these reasons, will not only convey the wrong information, mislead the audience, and more development of breeding rumors, cause large-scale mass incidents [16].

TV, radio and other authoritative information dissemination agencies in major events especially the behavior of an emergency, to a large extent affects the audience's judgment [19]. Before the earthquake rumors incident early stage of the rumors in the thinking of the mass media is just a routine information bulletin of seismological bureau to pay, but not to stand in the Angle of the audience to timely disambiguation; And in the process of the spread of rumors of mass, such as radio and TV in every region of the organizational units did not provide report and response, greatly hindered the audience and cognition and understanding of the truth [4]. Poor second our mass media also includes poor communications brings to the audience the anxiety and panic disorder [1]. Communication is of vital significance in the process of the spread of rumors, rumors in the event after the outbreak of large-scale, telephone signals, Internet information channel used by crazy, lead to signal not unobstructed, in complex environment, rumours communication not clear the reality of the apparent will intensify panic and anxiety.

64.3 Mechanism

Despite the headline-grabbing nature of these events and their known consequences, there are surprisingly few studies on systematically exploring how natural disasters affect the patterns of conflicts [6]. More attention has been paid to such aspects as disaster impact, risk management, and post disaster recovery. It has long been indicated that Sorokin [8] may be the first scholar who describes the polarizing effects of disasters aboveboard in his work "Man and Society in Calamity". Afterwards, Cuny gave a detailed description that natural disasters acted as triggers to affect social structure and development by bringing to the fore the social struggles and inequities inherent in society in his work "disasters and development", and suggested the governmental destabilization in the years immediately following a disaster [5]. It was a milestone that Drury and Olson [4] studied on the political unrest of natural disasters by adopting a statistical method in the late 1990s, followed by some other authors [3]. Philip and Marjolein [2] systematically probed into the problem that the existing natural disasters could significantly increase the risks of violent civil conflicts both in the short and medium term by using available data.

Some investigations into the casual relationship between natural disasters and conflicts were undertaken by many scholars [12]. Also, there are a number of claims about the conflict-inducing consequences of climate change had provoked a heated debate [20]. In recent years, historians have begun to explore the ways in which natural disasters are truly shaped by human actions. Geographers also have produced a large literature on the effects of natural hazards, and rare or extreme events, as well as how the impacts can be determined as much by prevailing social, economic, and political circumstances as by the event itself [24]. Despite the present study analysis, there is still a lack of emphasis on the specifics relating to natural disasters, natural disaster-based conflicts and researched that clearly examine, evaluate, and discuss the relationship [13].

Medium for information dissemination of extensive public opinion indicates that there is a widespread cause which leads to the information dissemination of media, inducing or implied form public opinion searches opinion. This opinion performance of information dissemination under the normal order not only leads to social events, but also increase the difficulty that public opinion control [14]. The role of media transmission can not be easily defined, and it is difficult for the gatekeeper function play the due role. Because of the influx of information, as well as the audiences' different demands it is hard for the medium to play their parts. As information transmission gatekeepers in today's information society will encounter various obstacles, the gatekeepers' roles can also not come into play easily [15].

Media, due to these reasons, will not only convey the wrong information and mislead the audience and more development of breeding rumors, but also cause large-scale mass incidents [17]. Concealing the information of rumors and false information brought about many troubles and inconvenience to the people's network life and even their real life. Medium in the spread of rumors will lead to the lack of social trust and the dilemma, triggering the emergence of the "media crisis of confidence", we know whether action oriented at the information will be ultimately determined by humans, and trust is the decisive factor leading to the social mistrust, the crisis of confidence in the mass media [16]. What people don't know is that the good and evil can not be regarded as the malicious behaviors of spreading information. However, malicious behaviors not only seriously interfere with the activities of people and destroy the credibility of the media, but also pose a serious threat to social stability and harmonious development [7].

64.4 Discussion

The damage of earthquake rumors involving homes is a matter of public interests and social stability [26]. In terms of earthquake rumors stemming from the public, they are caused by the psychology of the public's fear, but the rumors are resented. Therefore, controlling the earthquake rumors has a broad mass base. With regard to monitoring earthquake rumors, there are channels in fact, for example, the earthquake monitoring team, propaganda department, network regulatory network supervisor team, network media such as the news media, telecommunications, mobile operating agents can be found in urban and rural areas within a relatively short time when earthquake rumors are emerging, so, with the help of these institutions with proper treatment, the continuous spread rumors can be properly controlled [25]. Governments at all levels and the departments concerned shall, in accordance with the shock in conformity with the duties bestowed on the laws and regulations and relevant provisions, adopt various means and take the corresponding measures to strictly control the spread of the earthquake rumors, so as to reduce its harm to the society [21].

Once the earthquake rumors develop into events, decisive and effective measures must be taken according to the nature of the rumors, scale, communication channels, diffusion range, such as controlling the further spread of its social influence and effectively holding back its development [24]. Rumors in a wise man can be ended in a scientific way. When it comes to the analysis of earthquake rumors involving the disposal process, it is not difficult to find that there are still some problems or difficulties, such as identifying the earthquake rumors which are reported or not, information channel not free content on the distortion, the truth difficult to grasp the rumor, the rumor to de-fine, different sounds of rumors, different places lack of unified measures, people's ability to identify earthquake rumors for improvement, etc. [22]. To solve these difficulties or problems, the following measures can be taken as the solutions step by step [23].

With respect to news reports of the pass of wade seismic events, they may cause the public's misunderstandings or produce ambiguity involving information reported to the approval in accordance with the relevant procedure, upon examination and approval by the relevant departments of the rear [21]. Protection against and mitigation of earthquake disasters of normal should seek the truth from facts, and low-key processing should not be exaggerated. To grasp the orientation and initiative of the public opinion, once the earthquake rumors appear, the departments concerned should appear in front of the public right the first time, to tell the public the right information in a timely manner [16]. During the disposal of rumors, unified leadership and unified caliber should be guaranteed. When a department can not effectively deal with rumors, it should under the unified leadership of the government, multi-sectoral cooperation, multi-pronged and common disposals, take the timely and appropriate disposal of earthquake rumors [20]. When the so-called extremes meet, as well as the disposal of earthquake rumors and overreaction also backfire, the disposal of earthquake rumors will fail in effectively implemented, but also exert adverse effect on the earthquake rumors [26].

For different types of rumors, targeted measures, disposals and effective method can be taken. We need to improve the relevant disposal departments' credibility [26]. Any earthquake rumors are vulnerable in front of the science, and the key to disposal must be mentioned when the earthquake rumors allow the rational public to fully believe what the relevant departments told them are true. In terms of disposing the earthquake rumors, it is a tough task to be completed, because the earthquake prediction itself is a scientific problem in the world [26]. Some experts have a high level of randomness when dealing with such issues, so it is difficult to resolve them accurately, even explain some phenomena presenting more obvious loopholes, so that the public would rather believe in a communal letter expert [3]. In the long run, the public's trust in the relevant departments will also be discounted [10]. It is necessary to study and control such a situation, and freedom of speech cannot be neglected, which can cause unnecessary harm to social orders [19].

64.5 Conclusions

This paper is aimed at keeping people's subjectivity on the analysis of rumors, and multi-angle views on the problems objective and accurate. In the emergence and development of rumors, media does not only include the mass media, but also incorporate technology and supervision with the constraint conditions of new media and the media, so as to satisfy their own interests and fulfill a social responsibility for controlled rumors. In the process of control, giving priority to with the news media and the media plays a key role in it. By virtue of traditional print products, electronic media and emerging media network, information on rumors of textual research, discoveries and reports cultivate the audiences' consciousness and behaviors. In the process, this behavior in enterprises and government has formed a ruling and supervision over groups and individuals.

Through the rumors spread media characteristics, functions and phase analysis in combination with the theory of media analysis, this paper draws the following conclusions: first, the media dissemination of information is affected by the comprehensive social economy, politics, culture, so one-sided information dissemination and superficial understanding should be avoided, the problem of rumors spread should be treated correctly, to seek the appropriate solutions in an active manner. Second, there is the relationship between the government and the audience, so media needs to play a role effectively in the spread. We should always take these questions into consideration, and make steady efforts to contribute to the society. Third, the management of the government is not everything. Therefore, in order to ensure the healthy development of the media, work must be done to maintain a sound interaction and balance between the government and the majority of Internet users.

Acknowledgments This research was supported by the Science for Earthquake Resilience (Grant. XH14032Y). We appreciate this organization for its support in both finance and spirit. We appreciated these supports both in finance and in spirit. Further, we would like to thank all of the referees for their insightful comments and suggestions to improve this paper.

References

1. Bai D, Unsworth MJ et al (2010) Crustal deformation of the eastern tibetan plateau revealed by magnetotelluric imaging. Nat Geosci 3(5):358–362
2. Bordia P, DiFonzo N (2002) When social psychology became less social: prasad and the history of rumor research. Asian J Soc Psychol 5(1):49–61
3. Boyd SW, Butler RW et al (1994) Identifying areas for ecotourism in northern ontario: application of a geographical information system methodology. J Appl Recreat Res 19(1):41–66
4. Chen SF, Wilson CJ (1996) Emplacement of the Longmen Shan ThrustłNappe belt along the eastern margin of the tibetan plateau. J Struct Geol 18(4):413–430
5. Dwianto RD (1999) Patron-client relation reconsidered: comparing civil defense group in kanto earthquake and jakarta riots of May 1998. Int J Jpn Sociol 8(1):161–181
6. Galam S (2003) Modelling rumors: the no plane pentagon french hoax case. Phys A: Stat Mech Appl 320:571–580
7. Huang D, Zhang Q et al (2015) Example application of risk assessment technology based on acute poisoning accident dispersion simulation. In: Emerging Economies, Risk and Development, and Intelligent Technology: Proceedings of the 5th International Conference on Risk Analysis and Crisis Response, Tangier, Morocco, CRC Press, June 1–3. p 349
8. Hubbard J, Shaw JH (2009) Uplift of the longmen shan and tibetan plateau, and the 2008 wenchuan (m = 7.9) earthquake. Nature 458(7235):194–197
9. Kamins MA, Folkes VS, Perner L (1997) Consumer responses to rumors: Good news, bad news. J Consum Psychol 6(2):165–187
10. Prentice RC, Witt SF, Hamer C (1998) Tourism as experience: the case of heritage parks. Annal Tour Res 25(1):1–24
11. Reuveny R (2007) Climate change-induced migration and violent conflict. Polit Geogr 26(6):656–673
12. Rezaeian M (2013) The association between natural disasters and violence: a systematic review of the literature and a call for more epidemiological studies. J Res Med Sci Off J Isfahan Univ Med Sci 18(12):1103
13. Sandin P, Wester M (2009) The moral black hole. Eth Theor Moral Prac 12(3):291–301
14. Scheffran J, Brzoska M et al (2012) Climate change and violent conflict. Science (Washington) 336(6083):869–871
15. Schumacher JA, Coffey SF et al (2010) Intimate partner violence and hurricane katrina: predictors and associated mental health outcomes. Viol Victim 25(5):588
16. Tsai CH, Chen CW (2010) An earthquake disaster management mechanism based on risk assessment information for the tourism industry-a case study from the island of Taiwan. Tour Manag 31(4):470–481
17. Turner RH (1994) Rumor as intensified information seeking: earthquake rumors in china and the united states. In: Disasters, collective behavior, and social organization pp 244–256
18. Waizenegger A, Hyndman J (2010) Two solitudes: post-tsunami and post-conflict aceh. Disasters 34(3):787–808
19. Wang J, Iannotti RJ et al (2010) Co-occurrence of victimization from five subtypes of bullying: Physical, verbal, social exclusion, spreading rumors, and cyber. J Pediatr Psychol p jsq048
20. Watson JT, Gayer M et al (2007) Epidemics after natural disasters. Emerg Infect Dis 13(1):1
21. Wijkman A, Timberlake L, et al (1984) Natural disasters. In: Acts of God or Acts of Man Earthscan

22. Xu X, Wen X et al (2009) Coseismic reverse-and oblique-slip surface faulting generated by the 2008 MW 7.9 Wenchuan earthquake, China. Geology 37(6):515–518
23. Zeccola P (2011) Dividing disasters in aceh, indonesia: separatist conflict and tsunami, human rights and humanitarianism. Disasters 35(2):308–328
24. Zhang DD, Jim C et al (2006) Climatic change, wars and dynastic cycles in China over the last millennium. Clim Chang 76(3–4):459–477
25. Zhang DD, Zhang J et al (2007) Climate change and war frequency in eastern China over the last millennium. Hum Ecol 35(4):403–414
26. Zhang DD, Lee HF et al (2011) The causality analysis of climate change and large-scale human crisis. Proc Natl Acad Sci 108(42):17,296–17,301

Chapter 65
Parametric Analysis of Leadership Styles on Organizational Performance and the Mediating Role of Organizational Innovativeness

Muhammad Nazim, Rashid Saeed, Muhammad Suhail Sharif and Mehreen Ahmed

Abstract Traditionally leadership styles has greatly emphasized on the performance of organization. In our study we explore the effects of leadership styles (Transformational, Transactional and Laissez-Faire Leadership) on the organizational performance under the mediating role of organizational innovativeness. The research indicates that does innovation effects the overall performance of an organization or not? Aspects the way the leadership style might have an impact on organization Performance but in the presence of the organization's innovativeness this relationship gets boosted up or not? A quantitative research will be used by focusing the Pharmaceutical sector in Lahore 300 questionnaires will be distributed by using stratified random sampling used in the study.

Keywords Leadership styles · Organizational innovativeness · Organizational performance

65.1 Introduction

It is found that leadership styles are much effective to improve the organizational performance. Study prove that organizational innovativeness is the most important and sustainable source to gain competitive advantages. Manager's leadership is the important factor of organization's success. The quality of manager's leadership to influence

M. Nazim (✉) · M.S. Sharif · M. Ahmed
Department of Management Sciences, The Islamia University of Bahawalpur, Rahim Yar Khan, Pakistan
e-mail: nazimscu@gmail.com

R. Saeed
Department of Business Adminstration, Bahadur Sub-Campus of Bahauddin Zakariya University, Multan, Pakistan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_65

their subordinates by making them more satisfied, committed and in return increases productivity [11]. In organization transformational leadership style add positivity it is also report certain weaknesses such as ambiguity underlying its influences and processes [14]. Both transactional and transformational are significantly impact the performance of organizational [19]. Transformational, transactional and laissez-faire leadership styles add positively impact on the performance of organizational [18].

The aim of this research is to realize the importance of organizational performance. Firstly this study will explain three different leadership styles affecting organizational performance and secondly observing mediating role of organizational innovativeness between leadership styles and organizational performance. Previously there was no indication of observing relationship between leadership styles and organizational performance in the presence of innovativeness acting as mediator.

This article will highlight those prospective which will introduce new concepts in context of improving employee behavior towards goals achievements and organizational performance. The main theme of this article is realization of the facts that leadership is not only a personality trait but also has significant impact on organizational performance and also providing information about the human behavior.

Moreover, this particular research will be a source of contributing an idea which has not been studied together though organization performance and organization innovativeness has been studied separately but in this study it's for the very first time that all three variables are being studied together which will enable the researcher to probe out some of the findings and recommendations for the managers to learn more about effect of their style on organization performance and to device such policies which will enable them to create an atmosphere which makes the employees more committed and loyal not only towards their job but towards achieving the organization's goal.

65.1.1 Problem Statement

Leadership is an important element for an organization performance and while research for the relationship and effect of leadership styles on organizational performance, the statistical work has not been done to study the relationship between leadership styles and organization performance under the mediating effect of organizational innovativeness. Finally countries in the growing phase like Pakistan, need to know the contribution of different factors and the intensity of their impact on organizational performance that leads towards economic development.

65.1.2 Objectives

(1) To identify the effect of Transformational leadership on the organization performance.
(2) To identify the effect of Transactional leadership on the organization performance.

(3) To identify the effect of Laissez fair leadership on the organization performance.
(4) To identify the effect of Transformational leadership on the organizational performance under the effect of Organizational Innovativeness.
(5) To identify the effect of Transactional leadership on the organizational performance under the effect of Organizational Innovativeness.

To identify the effect of Laissez fair leadership on the organizational performance under the effect of Organizational Innovativeness.

65.2 Literature Review

The following section provides a summary of the academic literature that is relevant to this study. It includes a section on leadership and its styles, organizational commitment, and organizational performance.

65.2.1 Leadership

Researcher defines leadership as an effort to persuade the group of people through the effective communication procedure to reach definite goals. Leadership is the skill to persuade followers to work toward certain objectives and goals [13]. Leadership styles have been a tough and demanding topic for organizational effectiveness. Therefore diverse leadership styles have been considered across numerous decades and in current theory which was anticipated by Bass in which three styles as Transformational, Transactional, and Laissez-Faire Leadership [2]. The theory of leadership several studies were summarized into five broad theories namely, trait, behavioral, contingency or situational approach, contemporary integrative approach, and power and influence approach. There are numerous styles of leadership such as: laissez-faire, transactional and transformational leadership [11]. Dissimilar styles were desired for different situations and every leader required recognizing when to demonstrate a particular approach. there is no a single leadership style which is best for each situation since a leader may have knowledge and ability to deals effectively in one situation but may not materialize as effectively in a diverse situation.

65.2.2 Transformational Leadership

Transformational leadership is a charismatic leadership which converts idealization into realistic actions. Transformation can be defined as a linking of organizational approach and psychological characteristic which can lead an on the whole organizational change [15]. Moreover leaders can direct a higher level of psychological needs to groups and in return stimulate their commitment to the organization [8]. Transformational leaders also give importance to subordinate individual needs and personal development. It is helpful to build a close relationship with employees. Leaders give equal attention to each employee in different ways. They treat each individual in a fair way. Because of this biasness free leader attitude, employees feel more special, loyal and confident. To follow this leadership style, there is an attractive effect on the success of the employees [4]. They motivate employees to work with team for the team mission and goals and also the stability of this process. Leaders give confidence to employees to see outside what they already have [2].

65.2.3 Transactional Leadership

A person is defined as transactional leader who has the capacity to make subordinates consistent with existing environment and closely focuses on screening deviations and making amendments. Appreciating good performance and identifying errors in performance is also a leading role of transactional leader. One of the leading researchers indicates that transactional leader motivates the self-interest of employees towards work [9].

65.2.4 Laissez-Faire Leadership

Decentralized decision making is a key factor of Lassies-Faire Leadership style and no formal Boss-subordinate relationship exist in it [5]. Laissez-Faire Leadership style is characterized by subordinates making their own goals, set their rules and have own responsibilities for task completion. Laissez-Faire Leaders have freedom to take any decision [16].

65.2.5 Organizational Innovativeness

Organizational innovativeness (OI) is "an organization's overall innovative capability of introducing new products and services to the market, or opening up new markets, through combining strategic orientation with innovative behavior and process" [17]. Globalization has forced companies to innovate and design. Innovation can defined as a new idea, concept in the form of product, technology, production process or any new marketing strategy along with intellectual property [10]. Learning environment will be a big source of creating innovation [3]. Innovation is highly influenced by

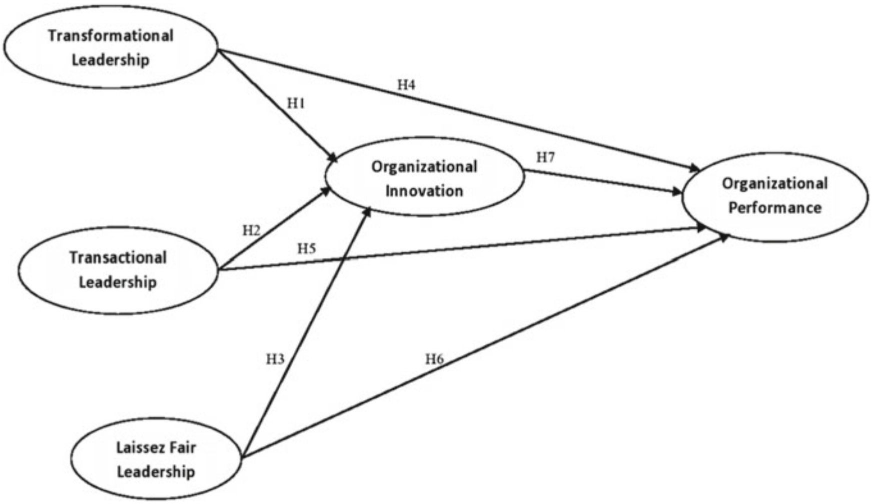


Fig. 65.1 Theoretical framework

transformational leadership style [7]. The concept of organizational innovation is different for business organization as compared to public organization in context of risk orientation [17] (Fig. 65.1).

65.3 Hypotheses and Theoretical Framework

Hypothesis 1 (H_1): Transformational leadership style has positive and significant impact on organizational innovation.

Hypothesis 2 (H_2): Transactional leadership style has positive and significant impact on organizational innovation.

Hypothesis 3 (H_3): Laissez faire leadership style has positive and significant impact on organizational innovation.

Hypothesis 4 (H_4): Transformational leadership style has positive and significant impact on organizational performance.

Hypothesis 5 (H_5): Transactional leadership style has positive and significant impact on organizational performance.

Hypothesis 6 (H_6): Laissez faire leadership style has positive and significant impact on organizational performance.

Hypothesis 7 (H_7): Organizational innovation has positive and significant impact on organizational performance.

Hypothesis 8 (H_8): Organizational innovation mediates the impact of transformational leadership style on organizational performance.

Hypothesis 9 (H_9): Organizational innovation mediates the impact of transactional leadership style on organizational performance.

Hypothesis 10 (H_{10}): Organizational innovation mediates the impact of laissez faire leadership style on organizational performance.

65.4 Methodology

This research would be quantitative in nature. In order to achieve the desired objectives, structured questionnaire will be used as a research tool for data collection. To measure the leadership styles (transformational, transactional and Laisses-Faire) and organizational Innovativeness (Product, Process and Marketing), 5 point likert scale will be used. In SPSS, multiple regression analysis, correlation analysis and factor analyses will be performed in this research. Convenient sampling technique will be used to conduct the research. Data will be collected through questionnaire from about 300 respondents. In this cross sectional study the primary data will be collected from professionals working in selected multinational companies in Pakistan, through questionnaires.

65.5 Analysis and Discussions

65.5.1 Reliability Analysis

The internal reliability for individual variable was tested by using cronbach's alpha. Nunnally [12] suggested that value of alpha equal are greater than 0.60 is sufficient for declaring items to be reliable. Table 65.1 shows values of cronbach's alpha for each variable and it may be noticed that each variable has higher reliability as each value is above 0.70.

Table 65.1 Cronbach's alpha values for each variable

Sr.	Variable	No. of items	Cronbach's alpha
1	Transformational leadership	13	0.784
2	Transactional leadership	10	0.71
3	Lassaiz faire	9	0.731
4	Organizational innovation	15	0.782
5	Organizational performance	10	0.788

65.5.2 Correlation Analysis

Correlation analysis was used to see the contribution of each leadership style on organizational innovation as well as on performance. Table 65.2 shows correlation coefficients for the relationship among all variables involved.

The results show that there is positive and significant relationship between transformational leadership and organizational performance ($r = 0.429$, $p = 0.000 < 0.01$). This means that transformational leadership style positively contributes towards organizational performance and by adopting this style organizational performance can be increased. It can also be shown that this leadership style is the major contributor of organizational performance. Transactional leadership style is also positively and significantly related with organizational performance ($r = 0.153$, $p = 0.017 < 0.05$) which shows that this leadership style can positively influence organizational performance. It can also be noticed from the results that this style is the least contributor of organizational performance. There is also positive and significant relationship between laissez faire leadership style and organizational performance ($r = 0.353$, $p = 0.000 < 0.01$). All the above results suggest that all the leadership styles included in this research are positively and significantly related with organizational performance. Further the results of correlation analysis show that organizational innovational is positively and significantly related with transformational leadership ($r = 0.378$, $p = 0.000 < 0.01$), transactional leadership ($r = 0.278$, $p = 0.000 < 0.01$) and laissez faire leadership ($r = 0.410$, $p = 0.000 < 0.01$) styles. It is found that organizational innovation can be most fostered by promoting laissez faire leadership style in the organization. Also there exists positive and significant relationship between organizational innovation and organizational performance ($r = 0.552$, $p = 0.000 < 0.01$).

Table 65.2 Correlations coefficients

	Transformational leadership	Transactional leadership	Laissez-faire leadership	Organizational innovation	Organizational performance
Transformational	1	–	–	–	–
Leadership	–	–	–	–	–
Transactional	0.281[b]	1	–	–	–
Leadership	0.000		–	–	–
Laissez-Faire	0.373[b]	0.416[b]	1	–	–
Leadership	0.000	0.000	–	–	–
Organizational	0.378[b]	0.278[b]	0.410[b]	1	–
Innovation	0.000	0.000	0.000	–	–
Organizational	0.429[b]	0.153[a]	0.353[b]	0.522[b]	1
Performance	0.000	0.017	0.000	0.000	–

[a]Correlation is significant at the 0.05 level (2-tailed)
[b]Correlation is significant at the 0.01 level (2-tailed)

65.5.3 Multiple Regression Analysis

Multiple regression analysis was used to test the hypotheses of this study. We developed two regression models to test the hypotheses of this article. Table 65.1 shows the results of multiple regression model in which the three leadership styles were taken as independent variables and organizational innovation was used as dependent variable. In this model the value of adjusted R^2 is 0.224 that reveals that 22.4 % of the total variation in organizational innovation is explained by three leadership styles that are taken as independent variables in this model. Also the value of $F = 23.968$ is significant which shows that this regression model significantly predict the dependent variable organizational innovation. The results of the model show that transformational and laissez faire leadership styles are significant positive predictors of organizational innovation ($\beta = 0.217$, $p = 0.000 < 0.01$ and $\beta = 0.220$, $p = 0.000 < 0.01$) but transactional leadership style was not found as significant predictor of organizational innovation ($\beta = 0.075$, $p = 0.148$). So our hypotheses H_1 and H_3 are accepted but H_2 is rejected.

Table 65.2 shows the results of multiple regression model in which the three leadership styles and organizational innovation were taken as independent variables and organizational performance was used as dependent variable. In this model the value of adjusted R^2 is 0.338 that reveals that 33.8 % of the total variation in organizational performance is explained by three leadership styles and organizational innovation that are taken as independent variables in this model. Also the value of $F = 31.496$ is significant which shows that this regression model significantly predict the dependent variable organizational performance. The results of the model show that transformational leadership style and organizational innovation are significant positive predictors of organizational performance ($\beta = 0.263$, $p = 0.000 < 0.01$ and $\beta = 0.4670$, $p = 0.000 < 0.01$) but transactional and laissez faire leadership styles were not found as significant predictors of organizational performance ($\beta = -0.079$, $p = 0.162$ and $\beta = 0.122$, $p = 0.039$). From this model we may see that organizational innovation is the major predictor of organizational performance. All the above results lead us to accept H_4 and H_7 but to reject H_5 and H_6.

65.5.4 Analysis for Mediation

Mediation analysis was used to see the indirect effect of leadership styles on organizational performance by taking organizational innovation as mediating variable. The process written by [6] followed by the criteria of [1] was used via SPSS to test mediating role of organizational innovation.

It was found that total effect of transformational leadership on organizational performance is statistically significant ($\beta = 0.4440$, $p = 0.000 < 0.01$). The same results were found for the total effect of transformational leadership on organizational innovation ($\beta = 0.3311$, $p = 0.000 < 0.01$). The effect of organizational innovation on organizational performance was found significant even after controlling the effect of organizational innovation ($\beta = 0.4958$, $p = 0.000 < 0.01$). Lastly, the effect of transformational leadership on organizational performance is significant after controlling mediator organizational innovation ($\beta = 0.2802$, $p = 0.0000 < 0.01$) and beta coefficient in this case has reduced to $\beta = 0.2802$ as compared to beta coefficient ($\beta = 0.4440$) in direct effect of X on Y. All the criteria proposed by Baron and Kenny [1] have been fulfilled and lead us to make conclusion that organizational innovation partially mediates the impact of transformational leadership on organizational performance. Therefore our hypothesis H_8 is accepted (Tables 65.3, 65.4, 65.5, 65.6, 65.7, 65.8).

It was found that total effect of transactional leadership on organizational performance is statistically significant ($\beta = 0.1470$, $p = 0.000 < 0.05$). Also the total effect of transactional leadership on organizational innovation ($\beta = 0.2259$, $p = 0.000 < 0.01$). The effect of organizational innovation on organizational performance was found significant even after controlling the effect of organizational innovation ($\beta = 0.6135$, $p = 0.000 < 0.01$). Lastly, the effect of transactional leadership on organizational performance is insignificant even after controlling mediator organizational innovation ($\beta = 0.0086$, $p = 0.8773 > 0.05$) and beta coefficient in this

Table 65.3 Regression coefficients

Model	β	t	Sig.
(Constant)	1.889	8.330	0.000
Transformational leadership	0.217	3.981	0.000
Transactional leadership	0.075	1.452	0.148
Laissez-faire leadership	0.220	4.261	0.000

Dependent variable: organizational innovation, $R = 0.483$, R square $= 0.234$, adjusted R square $= 0.224$, $F = 23.968$, $p = 0.000$, $p < 0.01$

Table 65.4 Regression coefficients

Model	β	t	Sig.
(Constant)	0.988	3.512	0.001
Transformational leadership	0.263	4.288	0.000
Transactional leadership	0.079	−1.404	0.162
Laissez-faire leadership	0.122	2.081	0.039
Organizational innovation	0.467	6.576	0.000

Dependent variable: organizational performance, R = 0.591, R square = 0.349, adjusted R square = 0.338, F = 31.496, $p = 0.000$, $p < 0.01$

Table 65.5 Direct and total effects

	coeff	se	*t*	*p*
$b(YX)$	0.4440	0.0610	7.3280	0.0000
$b(MX)$	0.3311	0.0526	6.2899	0.0000
$b(YM \cdot X)$	0.4958	0.0675	7.3413	0.0000
$b(YX \cdot M)$	0.2802	0.0592	4.7299	0.0000

Y = Organizational performance, X = Transformational leadership, M = Organizational innovation

Table 65.6 Bootstrap results for indirect effect of X on Y

	Effect	Boot SE	Boot LLCI	Boot ULCI
M	0.1642	0.0409	0.0981	0.2614

Y = Organizational performance, X = Transformational leadership, M = Organizational innovation

Table 65.7 Direct and total effects

	coeff	se	t	p
$b(YX)$	0.1470	0.0610	2.3930	0.0170
$b(MX)$	0.2259	0.0506	4.4637	0.0000
$b(YM \cdot X)$	0.6135	0.0681	9.0080	0.0000
$b(YX \cdot M)$	0.0086	0.0554	0.1546	0.8773

Y = Organizational performance, X = Transformational leadership, M = Organizational innovation

Table 65.8 Bootstrap results for indirect effect of X on Y

	Effect	Boot SE	Boot LLCI	Boot ULCI
M	0.1386	0.0396	0.0703	0.2262

Y = Organizational performance, X = Transformational leadership, M = Organizational innovation

case has reduced to $\beta = 0.0086$ which is near about zero. All the criteria proposed by Baron and Kenny [1] have been fulfilled and lead us to make conclusion that organizational innovation perfectly mediates the impact of transactional leadership on organizational performance. Therefore our hypothesis H_9 is accepted (Tables 65.9, 65.10).

It was found that total effect of laissez faire leadership on organizational performance is statistically significant ($\beta = .3280$, $p = 0.000 < 0.05$). Also the total effect of laissez faire leadership on organizational innovation ($\beta = 0.3227$, $p = 0.000 < 0.01$). The effect of organizational innovation on organizational performance was found significant even after controlling the effect of organizational innovation ($\beta = 0.5353$, $p = 0.000 < 0.01$). Lastly, the effect of laissez faire leadership on organizational performance is significant even after controlling mediator organizational innovation ($\beta = 0.1557$, $p = 0.005 < 0.01$) and beta coefficient in this case has reduced to $\beta = 0.1557$ as compared to beta coefficient ($\beta = 0.4440$)

Table 65.9 Direct and total effects

	coeff	se	t	p
$b(YX)$	0.3280	0.0560	5.2890	0.0000
$b(MX)$	0.3227	0.0465	6.9364	0.0000
$b(YM \cdot X)$	0.5353	0.0706	7.5847	0.0000
$b(YX \cdot M)$	0.1557	0.0555	2.8038	0.0055

Y = Organizational performance, X = Transformational leadership, M = Organizational innovation

Table 65.10 Bootstrap results for indirect effect of X on Y

	Effect	Boot SE	Boot LLCI	Boot ULCI
M	0.1727	0.0447	0.0980	0.2685

Y = Organizational performance, X = Transformational leadership, M = Organizational innovation

in direct effect of X on Y. All the criteria proposed by Baron and Kenny [1] have been fulfilled and lead us to make conclusion that organizational innovation partially mediates the impact of laissez faire leadership on organizational performance. Therefore our hypothesis $H_1 0$ is accepted.

65.6 Conclusions

The paper describes the effect of leadership styles on organization performance with the mediating role of innovativeness. The correlation analysis results show that there is positive and significant relationship between transformational leadership and organizational performance. Therefore transformational leadership style positively contributes towards organizational performance and by adopting this style organizational performance can be increased. The multiple regression analysis results of the model show that transformational leadership style and organizational innovation are significant positive predictors of organizational but transactional and laissez faire leadership styles were not found as significant predictors of organizational performance. It is suggested that adopting the innovation as mediator can stimulate the organizational performance.

References

1. Baron RM, Kenny DA (1986) The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J Personal Soc Psychol 51(6):1173
2. Bass BM, Bass R (2009) The Bass handbook of leadership: theory, research, and managerial applications. Simon and Schuster

3. Dickson PR (1996) The static and dynamic mechanics of competition: a comment on hunt and morgan's comparative advantage theory. J Mark 60:102–106
4. Greenberg J, Baron AR (2000) Behaviour in organisations 8:188–215
5. Griffin RW (2002) Management, 7th edn. Houghton Mifflin Company, New York
6. Hayes AF (2013) Introduction to mediation, moderation, and conditional process analysis: a regression-based approach. Guilford Press, New York
7. Jansen JJ, Vera D, Crossan M (2009) Strategic leadership for exploration and exploitation: the moderating role of environmental dynamism. Leadersh Q 20(1):5–18
8. Jiang MH (2002) Non-profit organization management. Bestwise, Taipei
9. Lu L (2011) Supervisors' leadership behaviors and subordinates' performance: moderating effects of the bicultural self. Advan Psychol 1:51–61
10. Mazzarol T, Reboud S (2006) The strategic decision making of entrepreneurs within small high innovator firms. Int Entrepreneurship Manag J 2(2):261–280
11. Mosadeghrad A (2003) Principles of health care administration. Dibagran Tehran, Tehran
12. Nunnally JC (1978) Psychometric theory
13. Robbins SP, Odendaal A, Roodt G (2001) Organisational behaviour: global and Southern African perspectives. Pearson South Africa, Pinelands
14. Singh N, Krishnan VR (2008) Self-sacrifice and transformational leadership: mediating role of altruism. Leadersh Organ Dev J 29(3):261–274
15. Silins HC (1994) The relationship between transformational and transactional leadership and school improvement outcomes. Sch Eff Sch Improv 5(3):272–298
16. Van Vugt SM M, Park J (2004) Kinship cues as the basis for cooperation in groups. University of Southampton: Unpublished manuscript
17. Wang CL, Ahmed PK (2004) The development and validation of the organisational innovativeness construct using confirmatory factor analysis. Eur J Innov Manag 7(4):303–313
18. Wongyanon S, Wijaya AF et al (2015) Analysis of the influence of leadership styles of chief executives to organizational performance of local organization in thailand (a case study of transformational, transactional and laissez-faire styles of leadership in pattaya city, laemchabang city municipality and chonburi provincial organization). Int J Appl Sociol 5(2):76–83
19. Zeb A, Saeed G, Ullah H, Rabi F et al (2015) Transformational and transactional leadership styles and its impact on the performance of the public sector organizations in pakistan. Abasyn Univ J Soc Sci 8(1)

Chapter 66
New Balanced Urban–Rural Development for Urbanization in Western China

Ronghe Liu, Changting Wei, Yi Lu and Zhineng Hu

Abstract Urbanization is an inevitable trend and objective requirement for the economic and social development. In recent years, urbanization level is unprecedented especially in developing counties. Just the same as other developing countries, China's urbanization has been entered into a pivotal period. This paper trying to summarize the new rural urbanization pattern of Chengdu capital of Sichuan Province hoping this can help other developing countries which have similar difficulties as China to get over the tough condition. First, an empirical study on new balanced urbanization (NBU) was carried out in Chengdu to get a deep comprehension of new rural urbanization in Chengdu. Second, undertook a documentary research on Chinese New Rural Construction to introduce the development background of new balanced urbanization. Finally, a deep analysis about new balanced urbanization in Chengdu was presented and the new balanced urbanization development pattern was abstracted. New balanced urban–rural development for rural urbanization pattern has already been test by the practice in Chengdu and got remarkable achievements. It is in accord with present and future international development demand and trend. In the meanwhile, new balanced urbanization is also a good sustainable urbanization example.

Keywords New rural urbanization · Sustainable · Low-carbon · Intensive · Intelligent · Green

---

R. Liu
Chongqing Agricultural Mechanization School, Chongqing 402160, People's Republic of China

C. Wei · Y. Lu · Z. Hu (✉)
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: huzn@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_66

66.1 Introduction

History and experience prove that urbanization is an inevitable trend and objective requirement for the economic and social development [15]. In the meanwhile, urbanization is an outcome of industrialization, agricultural modernization and informatization.

Most of the developed countries have finished the progress of urbanization. In the late 18th and early 19th centuries, the rapid industrialization touched off urbanization in the United States of America, and the American urbanization rate increased to 80.7 % in 2014 [32] World Urbanization Prospects (the 2014 Revision) reports that the urbanization rate of European countries is 73 % in 2014 [31]. European countries are already urbanized. Developing countries, in contrast, are under-urbanization. Among those developing countries, Africa and Asia countries' current tough urbanization condition are prominent. Africa and Asia countries remain mostly rural, with 40 and 48 percent of their respective populations living in urban areas [31]. According to 2001 and 2012 census, the Indian urbanization rate was 28.53 % in 2001 while the number only increased to 31.7 % in 2011 [3]. India urbanization was taking a slow pace. In Brazil, the increasing urban population brought ecological destruction. The seaweed decreasing 67.2 % kinds was a significant performance [23]. On account of urbanization, African average farm sizes will continue to fall for many years, posed special challenges in rural areas. Mean farm size dropped to 1.86 hectares in 2007 from 2.28 hectares in 1997 in Kenya [24]. South Africa urban cities ranked among the most non efficient, wasteful and not eco-friendly cities in the world [14]. There is an urgent need for valuable solutions for developing counties' urbanization difficulties.

Urbanization is a progress which means resource flowing to rural area [1], increasing urban population [11], growing numbers and scales of cities and towns [4], and life quality improving [12]. Urbanization systematic includes the rural areas and cities [34]. As for China towns (residential committee) are a special case included in urbanization systematic [27]. As a part of urbanization systematic, rural urbanization is a key step. To some content, new balanced urban–rural development for rural urbanization was put forward on the basis of New Rural Construction which is a main and indivisible element of rural urbanization.

"Intensive", "intelligent", "green, and "low-carbon", are essential for sustainable NBU, indicates sustainability of NBU. Intensive urbanization, which means large-scale and specialized production, will put more resources into smaller venues adopting new technologies and careful management. The energy and resource utilization structure will be changed to improve the domestic energy consumption efficiency [10, 35]. Green in urbanization mostly means green space, areas in city/urban areas and eco-development [37]. Low-carbon means low co2 emission level. When it comes to urbanization, low-carbon means energy efficiency and environmental construction in the urbanization progress [9, 18]. Intelligent, always show up in the phrases "intelligent city" in urbanization, which means information technologies large scale applied in city [17].

On the basis of a field research on the NBU and a documentary research on both Korean New Village Movement and Chinese New Rural Construction, a brief analysis on New Rural Construction was carried out. Then there was a detail analysis on NBU systematic and practicing in Chengdu. Finally, some useful urbanization recommendation for other developing countries would be carried out.

It is widely acknowledged that China is a country with the largest population in the world. And China's population density is pretty lager than other developed countries [2, 13]. The western area of China is a typical case with great development pressure of environment and population. And economy in the western area drops behind the eastern area of China [21, 29]. The condition in western area of China is a classic example of the difficult position of other developing countries. This paper tried to summary the successful experience during the progress of the new balanced urbanization in Chengdu-a western city in China. Hoping other developing countries can learn some useful lessons from China.

66.2 Research Framework

66.2.1 Empirical Study: New Balanced Urbanization in Chengdu, Western China

Field research, relevant information collection were the main methods used for the empirical study. Through a series of research projects on the urbanization, field research was conducted in capital of Sichuan province-Chengdu which is Chinese Pilot Zone for Balanced Urban–Rural Development. The field research was carried out in nearly 10 reprehensive counties in Chengdu. The geographical features and the urbanization development status of those counties were recorded to present the achievements in terms of sustainable development in those counties. The research team has carried out filed investigation in the following steps:

(1) Mid-March to early April 2014: Wenjiang district (area of Chengdu) was investigated. "New Modern Ecological Garden" was the construction goal of Wenjiang district from 2009. After several years of development, Wenjiang district has got great achievements in NBU. The peasantry was interviewed to get firsthand information.
(2) Mid-April to early May 2014: Longquanyi district (area of Chengdu) was investigated. Longquanyi district is a good example of NBU. The development practice of peach blossom valley and ecological plantation was recorded.
(3) Mid-May to early June 2014: Sansheng County (area of Chengdu) was investigated. Sansheng County (area of Chengdu) in Chengdu is another successful example of NBU. The "Happy Plum Trees", "Hongsha Village" and "happy farmers" are all excellent models. Its operations and achievements were summarized.

(4) Mid-June to July 2014: Dujiangyan City (area of Chengdu) and industrial park of Jinjiang district, Chengdu were investigated. They are masterpieces of NBU. Modern Agricultural Park of Chengdu and Sichuan Chengdu new hope Dairy Co. Ltd were closely observed and the development pattern was then summarized.

The research team had a personally experience about the urbanization achievements in Chengdu after the investigation.

66.2.2 Brief Analysis on New Rural Construction

A library and document search was undertaking including relevant books, newspapers, research papers, and official reports. Basis on the documental research, a simple analysis was carried out about the Chinese New Rural Construction and Korean New Village Movement. The NBU background, progress, results and the success and lessons were thereby well understood.

66.2.3 Deep Analysis: New Balanced Urbanization in Chengdu

As a Chinese Pilot Zone for Balanced Urban–Rural Development, Chengdu does a great job on urbanization. NBU was promoted in this area rapidly. And "intensive", "green", "low-carbon" and "intelligent" were reflected absolutely. Based on the four investigated in typical regions of Chengdu, the systematic of NBU in Chengdu was carried out the same as the practical operation.

66.3 Chinese New Rural Construction

Early 1950s, Chinese central government mapped out an important strategy on "building a new countryside" to overall coordinate urban and rural development. On account of the successful of Korean New Village Movement, there was a great mass favor for Chinese officer to set New Village Movement as an example [7, 25, 36]. Chinese officers would like to learn Korea New Village Movement experience, because the similarities of Korea and China [30]:

- South Korea and China had same conditions before urbanization. China, at few years ago, had a considerably productivity level with Korea in 1970s.
- Natural conditions were similar between China and Korea. Both were poor-resource countries.
- The two countries economic model were both government dominated development model. The government's macro-control ability was very strong.

- Similar cultural background. Korea and China were both under the influence of the Oriental Culture, and their mindset was remarkable similar.
- Government policies played an important role in policy assistance and resources mobilization.

Owing to the similar condition of China and Korea, Chinese government set New Village Movement as an example during the process of new rural construction. According to the experience of Korea, Chinese government focused on farmers and rural areas during New Rural Construction progress. After three stages (pilot and summary stage, popularization stage, and development and perfection stage), poor rural infrastructure, basic public service and agriculture productivity were improved. Supporting industry was cultivated. The target, farmers' income increasing, pushed forward the New Rural Construction development.

To some extent, New Rural Construction put great emphasis on rural areas development referring to Korean experience. The relationship between rural and urban development relatively draft less attention in the progress [26]. Problems, low efficient and environment damage, were exposed during the progress. The international condition has changed since the time when Korea promoted New Village Movement. And Chinese national condition was also different with Korea in some aspects. So combined the international development trend—"intensive", "green", "intelligent" and "low-carbon" with economic and social development, Chinese government proposed New Urbanization aiming at balancing urban and rural development further on the development and perfection stage of New Rural Construction.

Several regions were selected as Pilot Zone for Balanced Urban–Rural Development. And Chengdu was set as a reform pilot zone in 2007. In the last few years, Chengdu got great achievements in the new balanced urban–rural development for urbanization.

66.4 New Balanced Urbanization in Chengdu, Western China

66.4.1 New Balanced Urbanization Practical Operation in Chengdu

NBU in Chengdu aims at implementing "intensive", "intelligent", "green", and "low-carbon urbanization to balance urban–rural development. A green eco-system, which is an organic combination of mountains, water, forest, cities and villages need to be built during the urbanization progress, classified control the "Five Line (the red line (farmland protection scope), the blue line (water protection scope), the green line (green land protection scope), the purple line (historical and cultural heritage protection scope) and the yellow line (infrastructure building land protection scope)" [22, 28], then constructed new urban–rural interaction relationship which is services accelerating industry, industry promoting agriculture and cities driving countryside to cultivate new economic growth pole.

With the support of industry value chain and science-technology value chain which is:

- **Industry value chain**: Services accelerating industry and industry promoting agriculture were the mechanism how the industry advanced the development of the rural areas. With the promotion of industry value chain, Chengdu got successes in intensive development industry cultivation, intelligent and standard town construction, green and environmental friendly urban–rural interaction and low-carbon living community building,
- **Science-Technology value chains**: Cities driving countryside and urban–rural interaction were the means of science-technology value chain. The science and technology interaction among the cities, towns and countries was driven by this chain. Specifically, agriculture, forestry, livestock, fishery and tourism development and by-product processing were the driving force. In this way, Chengdu balanced urban–rural development and achieved city's rapid development at the same time.

The villages in Chengdu transformed into three kinds-characteristic-keeping villages, villages agglomeration around a center and villages sucked by cites according to local conditions. Corresponds to those three different types, villages carried out connotative, lengthwise and coordinated development then new village settlements, small towns along roads, the other kind small towns and satellite cities were built gradually.

Succeed NBU required effective implementation patterns. The urbanization patterns in Chengdu were summarized after the case study of typical districts and villages: Wenjiang, Dujiangyan, Longquanyi and Ssnsheng County. Three practical patterns were developed:

(1) **Joint household management $\Rightarrow$ professional farmers $\Rightarrow$ household farms $\Rightarrow$ farmer's cooperatives**: Through this development progress, intensive development and interaction of the rural and urban areas will be realized. Sansheng County is one of the good examples. In the last few decades, inefficient agriculture and obvious dual structure were the condition of Sansheng County (a village in the Chengdu city). Chengdu government carried out the construction of "Planting areas", "Happy Plum Trees", "Leasehold Farmland", "Chrysanthemum Garden" and "Lotus pond" in Sansheng County creatively considering the geographical advantage and local conditions. It worked out the problem of employment and capital. "Happy Plum Trees" developed tourism industrial with the support of plum culture and plum industrial chain, and farmers became professional plum trees planting workers Urban people contracting land in Sansheng County were the innovation of "Jiang Farmland". Transformation from traditional agriculture into experiential leisure industry were realized and the balanced urban–rural development was promoted. The development concept of "Chrysanthemum Garden", "Lotus pon" were humanities and eco-environment.

Intensive land using, ecological tourism development, and modern supporting facilities were the Sansheng County rural urbanization pattern. Sansheng County, in accordance with the city construction standards to speed up improvement of rural infrastructure, was now under the guidance of farmer's cooperatives to focus on economic developing.

(2) **Agriculture exemplary base ⇒ agricultural industrial demonstration zone ⇒ agricultural Sci&Tech park ⇒ industrial park**: (a) "New Modern Ecological Garden District" was the urbanization goal of Wenjiang (area of Chengdu) district. Modern agricultural park construction accelerated the local urban modern agriculture development. Organic combination of city funds, social capital and rural resources was carried out by the transfer project and enterprises development. Floriculture industry were chief industry of the region's modern agriculture. Leading agricultural enterprises promoted closer linkage between production and the market to guide development of the farmer's cooperatives and professional farmers. (b) Another typical successful case is Modern Agriculture Demonstration Garden in Chengdu. One "city" (Modern Agricultural Science and Technology City) with two bases (Modern Agricultural Demonstration Base and YouQing Modern Floriculture Industry Base) were the distinguishing feature of modern agriculture demonstration garden. With the recommendations given by Chengdu Academy of Agriculture and Forestry Sciences and Sichuan Agriculture University, construction a modern agricultural science and technology oriented agro-economic zone was its development goal. The operating mechanism-Government guidance, enterprise operation, social participation attracted research institutions and companies settled in it, thus industry cluster was formed.

(3) **High/new technology development zone ⇒ industry demonstration zone**: (1) Ecological planting chain: vegetables ⇒ fish, shrimp was carried out in Longquanyi, Chengdu. It was a compound and innovative technique which could reduce disease, purify water, conservation soil and water resources, and finally improve the overall efficiency. Sustainable cyclic development of fisheries and zero-emission, low-carbon economy development pattern was carried out. (2) Dujiangyan modern agricultural technology demonstration zone organically combined technology, industry, ecological, agricultural production, tourism. Industrial manufacture, digital management, ecology environment, intensive resource using were the achievements of Dujiangyan. Organic fruit and vegetable cultivation, processing and distribution of agricultural products, technical training were the auxiliary industry. After few years struggle, Dujiangyan has become an important window to display modern agriculture of Chengdu.

66.4.2 New Balanced Urbanization Achievements

Chen et al. [5] made a comparison between the sustainable urban development indicators system with reference the China context. The results showed that GDP Per

Capita, Proportion of educational funds expenditure in GDP, Per capita disposable income of urban residents, Green area per capita, and Energy consumption of per 10,000 output value appeared frequently in different indicator systems. GDP Per Capita was the economic development indicators for urbanization. Green area per capita was used to quantify the resource consumption and environment. Urban per capital consumption and urban per capital income implied the social poverty. Chen et al. [5] used Proportion of urban population and the built-up area to carry out the comprehensive evaluation of urbanization in China. Wang and Hu [33] used GDP Per Capita, Per capita disposable income, urban population proportion and Per capita arable land to evaluate the urbanization in China. Chengdu is in the western area of China, urbanization basic condition is the same as China except poorer farmers and weaker infrastructure. So the indicators which are suitable to China can also be applied in Chengdu. GDP Per Capita, Per capita disposable income of urban residents, urban population proportion, Urban per capital consumption, and Per capita arable land were the evaluation indicators of Chengdu.

NBU achieves remarkable results in Chengdu, western China preliminary. According to the official report of Chengdu Statistical Yearbook, the urban population probability in Chengdu decreased to 38.9 % by 2012 from 46.46 % in 2007. And GDP per capital in Chengdu increased to 69664 Yuan in 2012 from 22172 Yuan in 2007. Over the years there has been continuous increase of per capital income and consumption per capital of the farmers (see Table 66.1). Since the Xingdu district and Wenjiang district have become a part of Chengdu since 2000, the data before 2000 was not comparable. Only the data from 2000 to 2012 was presented.

As an agriculture country, rural areas' development destined to be the Chinese government concern. Since 2000, there have been official documents which mentioned rural construction. And Chinese government officially promoted New Rural Construction in 2005 [30]. And after several years' development, Chinese government put emphasis on balanced urban–rural development policy to promote rural construction.

Figure 66.1a shows that urban population decreased from 2000 to 2012 continuously while the total population in Chengdu increased. In China, urbanization, which is defined as the proportion of urban population of the total population [19].The decreased urban population associated with a variety of problem such as the loss of farming land (Fig. 66.2a), resource shortage in rural areas, rising crime rate, unemployment and environmental pollution [20]. GDP per capita (Fig. 66.1b) have increased since 2000, however, the increase speed was greater after 2007 when Chengdu was set as a reform pilot zone of balanced urban–rural urbanization development. Urban per capital pure income and urban per capital consumption (Fig. 66.2b) had the same situation with GDP per capital; it proved that farmers' living condition had been improved. GDP per capital and urban per capital pure income, urban per capital consumption which increased contemporarily indicated that urban and rural were coordinated development. However, urban development speed was lower than the whole Chengdu development rate. The NBU in Chengdu needed to do more work on rural development.

Table 66.1 The urban and rural data in western China from 2000 to 2012

Year	Urban population (%)	Urban net income per capital (Yuan)	Urban consumption per capital (Yuan)	Per capita arable land (ha)	GDP per capita (Yuan)
2000	64.44	2961	2201	0.042	12957
2001	65.21	3111	2353	0.041	14618
2002	64.44	3377	2549	0.037	16209
2003	63.02	3655	2721	0.035	17914
2004	57.18	4072	2954	0.034	19167
2005	49.73	4485	3074	0.033	21913
2006	48.21	4905	3344	0.031	24927
2007	46.46	5642	3988	0.031	29888
2008	45.60	6481	4565	0.030	34677
2009	44.77	7129	5012	0.028	39509
2010	43.4	8205	5796	–	48312
2011	39.3	9895	7033	–	59750
2012	38.9	11051	8061	–	69365

Note Data from Chengdu Statistical Yearbook [8]. The exchange rate of Yuan to Dollar is: 100 Yuan = 15.04 Dollars

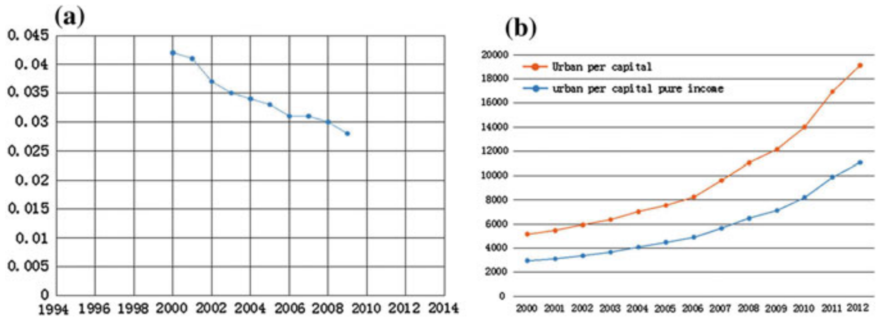


Fig. 66.1 Urban population scatter and urban per capital pure income and urban per capital consumption scatter

GDP per capita in 2012 became nearly triple of 2007. Thus the Chengdu economy has had an overall improvement since the advocating implementation of NBU in 2007. Urban residents' life had been improved analyzing from the data of urban per capital income and urban per capital. Chengdu made a good progress in solved the "three agriculture problem" and removed the dual structure.

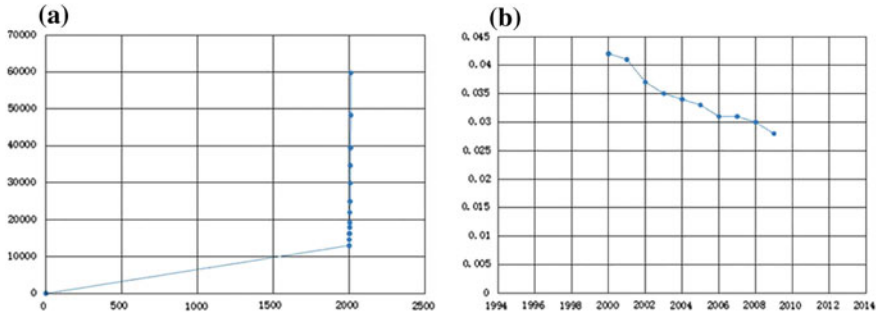


Fig. 66.2 Per capita arable land and GDP

66.5 Conclusion and Discussion

The new balanced urban–rural development urbanization is a systematic project. It's a way which meets the demand and trend of international development. In Chengdu's urbanization progress, NBU is promoted by Chinese government. And achievements were accomplished in Chengdu. By the deep analysis, NBU is in line with the current international condition. NBU is a valuable reference:

- NBU has already got some achievements in Chengdu. The Wenjiang district, Longquanyi district, Dujiangyan district and Sansheng County were all successful NBU practice. "Intensive", "green", "low-carbon", and "intelligent" were reflected in the NBU progress. Through the testing of practice, the NBU pattern was proved to be workable.
- China faced pretty hard condition which was much worse in western China before urbanization. The developed counties were already urbanized while the other developing countries also faced similar difficult as China. To some context, the NBU pattern in Chengdu was carried out in this kind of tough situation, so other developing countries with similar difficult condition can draw some lesson from NBU in Chengdu.
- Persistence of NBU meets the trend and demands of present and future sustainable development trend. The challenge brought by urbanization have led to global recognition of the need for sustainably and effective development patterns. NBU's four key elements "intensive", "green", "low-carbon" and "intelligent" were sustainable urbanization characteristics. NBU is in according with future development needs.

With the support of industry value chain and science-technology value chain, NBU promoted "intensive", "green", "low-carbon" and "intelligent" urban–rural construction under the guidance of government, enterprise, schools, research institutions and people. Living condition in rural areas was largely improved while farmers' income was increased ever since the coordinate-oriented urbanization was implemented in Chengdu. Economic in Chengdu also took a rapid development during this progress.

NBU in Chengdu got achievements initially, however some aspects need improvement to make the NBU more efficient. Drawing lessons from New Rural Constriction and Korean New Village Movement, farmer's education, environment protection and supporting industry needed to be improved. It is hoped that Chinese experience following the NBU in Chengdu will play a positive role in helping other countries solve the urbanization difficulties and to achieve the balanced urban–rural development better and faster. The following recommendations can be made to provide ideas for other developing country:

- Insist balanced urban–rural development in the urbanization progress. In this way, the gap between urban areas and rural areas can be removed gradually. And the urbanization can get some achievements.
- Rural development should be in line with its own characteristic. Develop industry (tourism, planting industry, processing agriculture products et al.) according to rural areas characteristics can solve the local farmers' employment in an eco-development way.
- There should be actively interaction between urban areas and rural areas. Services accelerates industry, industry promotes agriculture and cities drives countryside to cultivate new economic growth pole.
- Cultivate supporting industry to solve the farmers (who lost land during the urbanization progress) employment. Supporting industry can drive the local economic growth.
- In the initial development stage, industry promoting agriculture should be the power of urban development; however, interaction between industry and agriculture is needed in the later stage.
- Insist on sustainable development idea. Sustainable is international development need and trend.

In summary, NBU is a practical and efficient urbanization pattern. However, since the urbanization approach differs in various countries due to cultural, socio-economic and politically related issues, it is not possible to directly copy the Chinese experience to another country or design a uniform way for the whole world. Nevertheless, other developing countries can learn from Chinese experience, in conjunction with their own national conditions, an urbanization way for them can be carried out. This paper only discussed on the issues of new rural urbanization. Further study about cities' urbanization and the interaction mechanism of the city and rural areas should be carried out.

Acknowledgments This research was supported by the projects XQ14B04 and SKZX2015-SB87.

References

1. Abdissa F, Degefa T (2011) Urbanization and changing livelihoods: the case of farmers' displacement in the expansion of Addis Ababa. In: THe demographic transition and development in Africa, Springer, Heidelberg, pp 215–235
2. Bank TW (2014) Population density (people per sq. km of land area). In: The world bank: food and agriculture organization and world bank population estimates. http://data.worldbank.org/indicator/EN.POP.DNST
3. Chapter 5 Trends in urbanization (2011) Provisional population. http://www.censusindia.gov.in/2011-prov-results/paper2-vol2/data_files/AP/Chapter_IV.pdf
4. Chan RC, Shimou Y (1999) Urbanization and sustainable metropolitan development in China: patterns, problems and prospects*. GeoJournal 49(3):269–277
5. Chen M, Lu D, Zha L (2010) The comprehensive evaluation of China's urbanization and effects on resources and environment. J Geogr Sci 20(1):17–30
6. Chen M, Liu W, Tao X (2013) Evolution and assessment on China's urbanization 1960–2010: under-urbanization or over-urbanization? Habitat Int 38:25–33
7. Chen Z, Zhou B et al (2006) The "new village drive" in Korea in the 1970s: a good example for China today. Agric Econ Quest 2:72–77 (in Chinese)
8. Chengdu Bureau of Statistics (2013) Chengdu statistical yearbook 2000–2012. (in Chinese)
9. Dhakal S (2009) Urban energy use and carbon emissions from cities in China and policy implications. Energ Policy 37(11):4208–4219
10. Dong S, You F, Zhang X (2004) Environmental sustainability and scenarios of urbanization in arid area: a case study in Wuwei city of Gansu province. In: Optical science and technology, the SPIE 49th annual meeting, international society for optics and photonics, pp 109–123
11. DSilva MU, Agarwal V, Sohn S, Sharma V (2014) Urbanization and strategic health communication in India. In: Strategic urban health communication, Springer, Heidelberg, pp 159–172
12. Fragkias M, Güneralp B, et al (2013) A synthesis of global urbanization projections. In: Urbanization, biodiversity and ecosystem services: challenges and opportunities, Springer, Heidelberg, pp 409–435
13. Fu X, Shen Y et al (2016) Analysis of urbanization based on center-of-gravity movement and characteristics in songhua river basin of china and its southern source sub-basin between 1990 and 2010. Chin Geogr Sci 26(1):117–128
14. Goebel A (2007) Sustainable urban development? low-cost housing challenges in South Africa. Habitat Int 31(3):291–302
15. Juan S, Shan D (2012) The problems in the course of China's urbanization. In: Engineering education and management, Springer, Heidelberg, pp 173–177
16. Kim WB (1988) Population redistribution policy in Korea: a review. Popul Res Policy Rev 7(1):49–77
17. Komninos SE N (2009) Intelligent cities: R&D offshoring, web 2.0 product development and globalization of innovation systems
18. Li J (2008) Towards a low-carbon future in China's building sectorła review of energy and climate models forecast. Energ Policy 36(5):1736–1747
19. Li F, Liu X et al (2009) Measurement indicators and an evaluation approach for assessing urban sustainable development: a case study for China's jining city. Landsc Urban Plan 90(3):134–142
20. Li S, Ma Y (2014) Urbanization, economic development and environmental change. Sustainability 6(8):5143–5161
21. Liu Y, Huang X et al (2014) Environmental effects of land-use/cover change caused by urbanization and policies in southwest China karst area-a case study of Guiyang. Habitat Int 44:339–348
22. Long H, Liu Y et al (2010) Building new countryside in China: a geographical perspective. Land Use Policy 27(2):457–470
23. Martins CD, Arantes N et al (2012) The impact of coastal urbanization on the structure of phytobenthic communities in Southern Brazil. Mar Pollut Bull 64(4):772–778
24. Masters WA, Djurfeldt AA et al (2013) Urbanization and farm size in asia and africa: implications for food security and agricultural research. Glob Food Secur 2(3):156–165

25. Mia B (2006) Fuzzy variableson the several key issues in the promotion of the new countryside construction. J China Natl Sch Adm 2:28–31 (in Chinese)
26. Ministry of Housing and Urban-Rural Development of People's Republic of China (MOHURD) (2010) Group interview background information on China's urbanization opportunities and challenges and urban development. (in Chinese)
27. Qin B, Zhang Y (2014) Note on urbanization in China: urban definitions and census data. China Econ Rev 30:495–502
28. Shen L, Zhou J (2014) Examining the effectiveness of indicators for guiding sustainable urbanization in China. Habitat Int 44:111–120
29. Tao Y, Li F et al (2016) Environmental impacts of China's urbanization from 2000 to 2010 and management implications. Environ Manag 57(2):498–507
30. Tu B (2004) An inspiration of korea new village movement to new socialist countryside in China. PhD thesis, Southwest University, Xi'an, (in Chinese)
31. United Nations DoE, Social Affairs PD (2014) World urbanization prospects: the 2014 revision, highlights (st/esa/ser.a/352)
32. U.S. Census Bureau 2010 Census (2010) United states summary: 2010 population and housing unit counts 2010 census of population and housing
33. Wang W, Hu X (2014) On the view of sustainable development: the new urbanization evaluation and construction study of Shaanxi. Proceedings of the 18th international symposium on advancement of construction management and real estate. Springer, Berlin, pp 27–40
34. Wang F, Liu Y (2015) How unique is 'China model': a review of theoretical perspectives on China's urbanization in anglophone literature. Chin Geogr Sci 25(1):98–112
35. Wu D, Zhang W, Wu Y (2014) A study of rural livestock and poultry breeding pollution problems in China's urbanization process. In: Proceedings of the 18th International symposium on advancement of construction management and real estate, Springer, Heidelberg, pp 1–10
36. Zhang J, Dai Q, Xiang F (2001) Rural development in western China development: on the saemaul undong movement in Korea and its inspiration to rural constrction in western China. Financ Econ 1:71–74 (in Chinese)
37. Zhou X, Wang YC (2011) Spatial-temporal dynamics of urban green space in response to rapid urbanization and greening policies. Landsc Urban Plan 100(3):268–277

Chapter 67
Regional Water Resource Allocation Problem in Multi-agent Game: Taking the Water Rights Transfer as Example

Jingqi Dai, Zongmin Li and Nataliia Ivanova

Abstract Regional water resource allocation problem (RWRAP) is a growing concern in the world where limited resources like fresh water are in greater demand by more parties. Cooperation over allocations often involves multiple groups who own different disparate social, economic and political status, seeking a management solution for a wide range of demands. In this study, a multi-agent model is developed for tackling a RWRAP on the basis of the water rights transfer in a regional level. In contrast to previous studies, this paper designs rules of multi-agent cooperation in water rights transfer to ensure the equity of water resource allocation, which always exists unfair phenomenon. Finally, through analysis of model application in water rights transfer, we prove the model is viable and efficient.

Keywords Water resource allocation · Multi-agent Game · Water rights transfer

67.1 Introduction

With the development of societies and economies around the word, the RWRAP is a growing concern in the world where limited resources like fresh water are in greater demand by more parties [8]. There is a growing recognition that human impacts on freshwater systems can ultimately be linked to human consumption, and issues such as water shortages and pollution can be better understood and addressed by considering production and supply chains as a whole [5]. Consequently, this

J. Dai · Z. Li (✉)
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: lizongmin@scu.edu.cn

N. Ivanova
Eurasian Linguistic Institute of Moscow State Linguistic University (Irkutsk)
Russia, Irkutsk 664025, Russia

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_67

contradiction between the water supply and demand has become a major constraint to economic development in many areas with water shortages becoming more severe because of the often geographically and temporally uneven distribution of regional water resources [2]. Conflicts often arise when different water users compete for a limited water supply. Water allocation among the regions needs to consider three basic key principles: equity, efficiency and sustainability [4]. Equity ensures that all the stakeholders can be equal to enjoy rights of water allocation in the region. Efficiency is considered because of all agents' desire to obtain more benefits as possible. Under sustainability, water needs to be utilized now and future, ensuring ecological environment undamaged. However, it's difficult to fulfill all three principles.

Previous research has mainly involved in distribution of original water rights, leaving little care for water rights transfer. Since the 2000 Ministerial Meeting of World Water Forum held in the Hague, water rights have been actively explored in areas, such as theoretical frameworks, policies and regulations, and reform and practice [13]. Water rights management is a new resources management system incorporating a mechanism that combines a regional authority's macrocontrol with market regulations. When water rights transfer is conducted in regional water resource allocation, all kinds of water users are considered relatively independent under a cooperation environment. Therefore, the regional water resource allocation based on water rights under market mechanisms is considered to be a type of multi-agent game. The decision makers choose the strategies through a operational decision-making process,which is called a game decision-making problem. Sechi and Zucca [9] studied a bankruptcy game approach in Mediterranean regions about water resource allocation. Tu, Zhou et al. gave administrative and market-based allocation mechanism for regional water resources planning by a multi-objective bi-level programming model [11]. Zhou and Guo et al. presented integrated optimal allocation model (IOAM) for complex adaptive system of water resources management in Dongjiang River basin located in the Guangdong Province of China [14]. Shafie-khah, Miadreza et al. studied a new stochastic multi-layer agent-based decision making model to study the behavior of market participants in the future smart gid [10]. In this paper, we study RWRAP in multi-agent game by modeling profit functions of the game model and analysis the model to apply it in the water rights transfer.

The paper is structured as follows: The next section presents the background information, including problem statement, multi-agent team and game theory in multi-agent system. Section 67.3.1 presents game models by designing management structure about water rights transfer and presents each agent's profit function of game model. Section 67.4 discusses model application in water rights transfer. The paper closes with a conclusion in Sect. 67.5, which summarizes the main contents and contributions of this paper (Fig. 67.1).

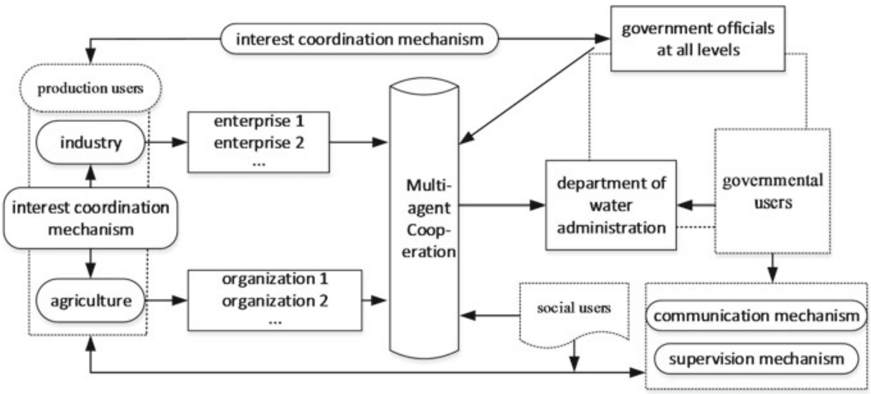


Fig. 67.1 Regional water resource allocation with multi-agent

67.2 Background Information

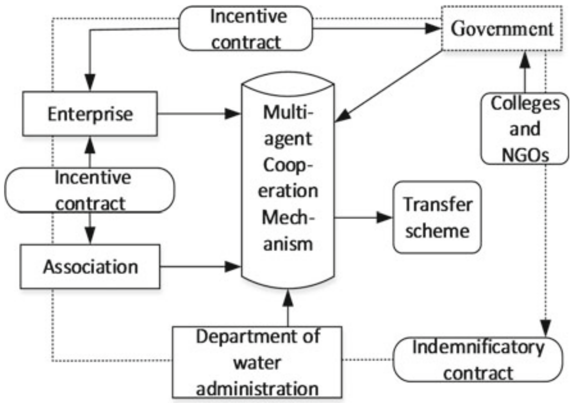
67.2.1 Problem Statement

To establish game models, the problem is introduced firstly.

Under market mechanisms, owning to regional water resource allocation problem has more than one decision makers, there would be a multi-agent game. All agents are making decisions to achieve their relative satisfaction results. We assume that there are three different water users: governmental users, production users and social users. In the water management system, the governmental users have special function and status. Although local government's behaviors are subject to the central government commands and regulations, they possess absolute power in regional water resource allocation who can have jurisdiction over its water administrative department. The corresponding water administrative department is in charge of water administration work of government departments, under the local government' leadership and having the power of controlling of water resource at the same time. Production users are composed by all kinds of industries of national economy. They would like to improve the water use efficiency so that they can obtain more economic efficiency. The last one is the social water users, whose form are all kinds of independent sets of nongovernmental organizations (NGO), without exploitation of water resources and not to make a profit. Certainly, it includes some nonprofit groups and organizations to use water resources for their targets, to coordinate the relations of these groups and organizations, and to create a better production environment. Therefore we can regard it as nonprofit organization. In China, it contains associations and the working groups, usually initiated by the folk (Fig. 67.2).

Water resource management has dynamic characteristics. In China, the sound water management regime hasn't been established, and managers always distribute water by experiences rather than based on scientific analysis and accurate historical

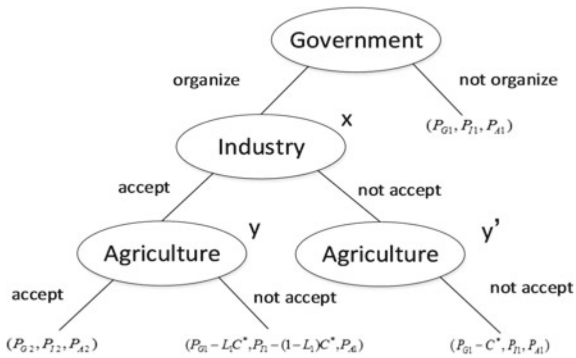
Fig. 67.2 Multi-agent cooperation rules



data. From the point of social attribute, different agents have divergent cognition over water resource, so as their ways of using and the attitudes to water resource. Exploring regional water resource allocation problem under the environment of conforming to the actual conditions of our country is a more difficult problem. There are some disadvantages of multi-agent cooperation under the premise that we emphasis on social justice and harmonious. Traditional water resource management is always overdependent on government regulations and administrative coercive measures, rather than taking a full consideration of all agents' appeals, leading to high transaction costs. Besides, lacking of cognition of various forms of value of water resource is also a significant conflict that would result in ignoring different agents' interests. In addition, executive-led mode has already can't achieve the optimal allocation of water resources. As a result, to attain equal, efficient and sustainable cooperation mode is the future trend in water resources governance multi-agent game.

Therefore, the RWRAP with multi-agent in this paper can be summarized as a multi-agent game, which pursuits to maximize the interests of all agents (see Fig. 67.3).

Fig. 67.3 The game process of the water rights transfer



67.2.2 Multi-agent Team

Assume a set of agents $N = \{i = 1, 2, \cdots, n\}$, where n is the number of agents. Each member has to know the status of the other members to ensure cooperation and coordination among multi-agent team, and therefore members have to communicate with each other. In this structure, no external command is provided to any members of the team, and the goal is to make all agents get relatively satisfactory solution.

67.2.3 Game Theory in Multi-agent System

We present a general description of the game theory in a multi-agent system to provide theoretical support for the next section. Game theory is a branch of economics that studies interaction between self-interested agents. Game theory has its roots in the work of von Neumann and Morgenstern's "theory of Games and Economic Behavior" book in 1994 which mainly dealt with quantitative game theory methods [1]. Game theory can be used to predict how people behave, following their own interest, in conflicts. The classic game theoretic problem requires each multi-agent obtain the best and the most rational overall outcome which depends critically on the choice made by all agents in the scenario. It means that an agent to make the choice that optimizes its outcome should consider other agents' decision, and must assume they will act so as to optimize their own outcome. However, what we actually need is relatively satisfied solution rather than globally optimal solution.

Game theory involves multi-agent system literature largely through the work of Jeffrey Rosenschein and colleagues [3, 6, 12]. His Ph.D. thesis used game theoretic techniques to analysis a range of multi-agent interaction system. Since it, coordination arises because of the assumption of mutual rationality. The most notable application of game theory to multi-agent system has been in the area of negotiation which is the process that agents can reach agreements on the matters of common interest.

As noted above, designing of cooperation mechanism about water rights transfer in RWRAP involves the design of protocols such that these protocols have certain desirable properties. Possible properties include as follows.

(1) Individual rationality

In the multi-agent system, individual rationality is essential when the protocol"playing by the rule" is in the best interests of participants [1]. Without individual rationality, there is no incentive for agents to engage in negotiations. Besides, to a certain extent, individual rationality guarantees the relative fairness of the solution because they wouldn't yield to any other agents' unreasonable decision.

(2) Nash equilibrium

In game theory, the Nash equilibrium is a solution concept of a non-cooperative game involving two or more players, in which each player is assumed to know the equilibrium strategies of the other players, and no player has anything to gain by changing only their own strategy [7]. If each player has chosen a strategy and no player can benefit by changing strategies while the other players keep them unchanged, then the current set of strategy choices and the corresponding payoffs constitutes a Nash equilibrium. The reality of the Nash equilibrium of a game can be tested using experimental economics method. Nash equilibrium can promise all agents with an incentive to behave in a particular way, which is called a state of stability.

67.3 Game Models

67.3.1 Management Structure of Water Rights Transfer

This section takes the RWRAP in multi-agent as a dynamic game. Unfortunately, traditional Nash equilibrium cannot be a reasonable solution in dynamic game, because participants' actions have sequence, that the latter's actions depend on the former's and when the former decision maker choose his strategy, he cannot take the influence of the strategy which may bring the latter into account. Selten's subgame perfect Nash equilibrium is a kind of important improvement of traditional Nash equilibrium, which distinguishes reasonable Nash equilibrium with unreasonable Nash equilibrium.

The present practical situation of water rights transfer proved that it can promote the development and use of regional water resource. However, there are some problems exist in water rights transfer as follows:

(1) Interest coordination problems

According to the analysis of water resource value, we know that value of water resource contains direct value, exterior value and potential value. Respectively, direct value contains the property value of water resources, labor value and utility value; exterior value includes gains or losses in a different way of water resource utilization and its marginal gains or losses; potential value is based on the first two value which contains satisfaction of the current life status, expectations of future development and security sense of life and so on.

In general, direct value is each agent's dominant profit which can be directly displayed in the vioprofit functions. However, exterior value and potential value are not always reflected in the profit functions. In the future, if water rights transfer cannot satisfy demands of region development, the agricultural agent would take the farmland transfer. This kind of behavior will let farmers lose water resource's exterior value and potential value. Only let agricultural agent full participate in water resource management, can interest coordination problem be solved greatly.

(2) Adjustment amount of water problems

Transfer of water rights can increase economic value of water resource, but it can also bring two significant dilemmas:

In recent years, the scale of industrial production has been greatly increasing at the cost of the sharp rise of industrial pollutants emissions, which have lead to serious destruction of ecological environment. To solve this problem from the source, beneficiaries cannot only enjoy the interests of the transfer but also to undertake the due obligations. Industry and local government should take responsible to both economic construction and ecology environment.

Owing to transfer brings benefits to economic development and improves the standard of living, beneficiaries, especially agricultural water users, always sale too much water resource so as to obtain more benefits. Nevertheless, this behavior would do harm to social stability and grain production safety, which is a kind of unsustainable development action.

(3) Maintain transfer problems

The existing transfer mechanism is done by compensation, and the most is a one-time payment. This way lacks feedback, because some direct beneficiaries don't participant into the compensation mechanism but passively acceptance the result. What's more, relevant policy lacks adaptability, but according to the experience or fixed model to calculate.

In summary, we call it "participation", "share", and "adaptation". By combing the beneficiaries of regional water resource, this paper establishes multi-agent cooperation rules to achieve efficient use of water resource (see Fig. 67.3). To achieve this target, each agent would conduct interactive strategy game on the basis of their policy set to attain multi-agent equilibrium and to get equilibrium condition, that is, cooperation rules. According to the stakeholder theory and Mitchell score-based approach, we determined 17 stakeholders of the water rights transfer between industries (see Table 67.1).

67.3.2 Profit Functions of the Game Model

The following symbols are used in this paper (Table 67.2):

In traditional mechanism, the profit of government agent contains industrial tax and project cost, which includes compensation for the interests of farmers and its own management cost. It can be expressed as follow:

In traditional mechanism, the profit of government agent contains industrial tax and project cost, which includes compensation for the interests of farmers and its own management cost. It can be expressed as follow:

$$\mathrm{P}_{\mathrm{G1}} = q(t + \Delta t) \times r_1 + C - [(1 - \psi)(C + \varepsilon) + A_1 + A_2 + A_3]. \quad (67.1)$$

Agriculture income equal production gain and compensation:

$$\mathrm{P}_{\mathrm{A1}} = p(s - \Delta t) + \varepsilon. \quad (67.2)$$

Table 67.1 The classification of stakeholders in water rights transfer

No.	Agents'type	Stakeholder	Legitimacy		Power		Urgency	
			Property	Degree	Property	Degree	Property	Degree
1	Water administrative	Administrative organization	√	S	√	S	√	S
2	Subject	Water conservancy organization	–	–	√	S	√	S
3		Judicial supervision institutions	–	–	√	W	√	W
4		Other institutions	–	–	√	W		W
5	Water market subject	Water supply department	√	W	√	W	–	–
6		Production department	√	S	√	S	√	S
7		Local residents	√	S	√	S	√	S
8		Financial institution	–	–	–	–	√	W
9		Consulting agency	–	–	–	–	√	W
10		Shareholders and employees	√	W	√	W	–	–
11		Product consumer	√	W	–	–	–	–
12	Water public subject	Local residents offspring	√	W	–	–	–	–
13		Nearby residents	√	W	–	–	–	–
14		Scholar	–	–	√	S	–	–
15		NGO	–	–	√	W	–	–
16		Critics and media	–	–	√	W	–	–
17		Social mass	–	–	–	–	√	W

√ represents having this kind of character; —represents not having this kind of character; *S* represents that degree of owning property is strong; *W* represents that degree of owning property is weak

Table 67.2 List of notations

Symbols	Implication	Symbols	Implication
$C = C_1 + C_2 + C_3$	The project cost	η, δ	Revenue sharing coefficient
C_1	The price of water resource	Δt	Adjusting water volume
$C_2 = C_{21} + C_{22}$	The water price of project. C_{21} is unit cost of water supply and $C_{22} = C_{21} \times 2\,\%$ is unit profits of engineering water supply	τ	Parameter of ecological compensation coefficient where there equals 2.5 %
$C_3 = C_{31} + C_{32}$	Ecological compensation. $C_{31} =$ price of enterprise sewage water emission and $C_{32} =$ cost of ecological protection	v	Allocation coefficient of water benefit where there equals 0.6
$\varepsilon = \varepsilon_1 + \varepsilon_2$	Compensation of farmers' loss. $\varepsilon_1 =$ compensation for agricultural opportunity income and $\varepsilon_2 =$ compensation for living	L_1'	In the mechanism of multi-agent cooperation game, parametric description range from the form of L_1
r_1	Industrial tax rate	ψ, ϕ	Share coefficient of water conservancy project
s	Agricultural water volume	A_1	Decision-making cost
t	Industrial water volume	A_2	Implementation cost
p	Unit output of agricultural water	A_3	Supervision cost
q	Unit output of industrial water		

Taking uncontain-Δt part of C, $\varepsilon = \varepsilon_1 + \varepsilon_2 = vp\Delta t + \varepsilon_2 = 0.6p\Delta t + \varepsilon_2$ and ε_2 as a constant

Profit of industry includes production gain and the costs. What's more, the costs are consist of tax, project costs and compensation of famers:

$$\mathrm{P}_{\mathrm{I1}} = q(t + \Delta t) - [\psi(C + \varepsilon) + q(t + \Delta t) \times r_1]. \tag{67.3}$$

So, the profit function is the sum of the above three:

$$\mathrm{P}_1 = q(t + \Delta t) + p(s - \Delta t) - (A_1 + A_2 + A_3). \tag{67.4}$$

Under the multi-agent cooperation mechanism, profit of government agent, agriculture income and profit of industry would turn into following form:

$$\mathrm{P}_{\mathrm{G2}} = q(t + \Delta t) \times r_1 + C - [(1 - \phi)C + A_1' + A_2' + A_3'], \tag{67.5}$$

$$\mathrm{P}_{\mathrm{A2}} = p(s - \Delta t) + \delta \times (1 - r_1)q\Delta t, \tag{67.6}$$

$$\mathrm{P}_{\mathrm{I2}} = qt + \eta \times (1 - r_1)q\Delta t - [\phi C + qt \times r_1]. \tag{67.7}$$

So, profit function is also the sum of the above three:

$$\mathrm{P}_2 = p(s - \Delta t) + q(t + \Delta t) - (A_1' + A_2' + A_3'). \tag{67.8}$$

67.4 Analysis of the Game Model

As the profit function established in last part, we can conclude the game process of the water rights transfer, see Fig. 67.3.

Among the parameters, C^* is the cost of organizational change, needed by mechanism transformation. So, we can get Nash equilibrium through backward induction which are (organize, accept, accept) and (not organize, not accept, not accept), as the result are (P_{G2}, P_{I2}, P_{A2}) and (P_{G1}, P_{I1}, P_{A1}). Based on subgame perfect Nash equilibrium, we are to further discuss the equilibrium results, that is, equilibrium strategy's behavior rules should be optimal in each information set. To accelerate water rights transfer to realize in multi-agent cooperation game, information set need reflect both industry and agriculture's preference. In this situation, when $P_{G2} > P_{G1}$, $P_{I2} > P_{I1}$, $P_{A2} > P_{A1}$, we call (P_{G2}, P_{I2}, P_{A2}) as subgame perfect Nash equilibrium in this game model. Therefore, to realize multi-agent cooperation, there are two conditions should be satisfied that the first one is improvement of agents' earnings and the second one is increasing of communication so as to improve information sets.

67.4.1 Application

On the basis of the game analysis results, we can gain cooperation rules of multi-agent cooperation mechanism, containing two parts. One is incentive contract, used to encourage every agent to participate in cooperation. This kind of rule is mainly to improve each agent's benefits, designing contract among direct beneficiary (industry), direct damage agent (agriculture) and beneficiary (industry and government). Another is indemnificatory contract which can be applied to promote and maintenance multi-agent cooperation. The rule mainly implements communication of the existing information sets and further improves information sets.

(1) Incentive contract

The core conflict of water rights transfer is industrial and agricultural interests contradiction. In order to achieve multi-agent cooperation, we should reconstruct interests relationship between industry and agriculture, to eliminate conflict. In traditional mechanism, industrial and agricultural interests would increase with Δt's growth. On the background of promotion of the region development, government support can completely realize $\psi < q - qr_1/0.6p$, making industrial revenue keep increasing. To satisfy both $\delta > p/(1-r_1)q$ and $\eta(1-r_1)q > 0$ under the multi-agent cooperation, industrial and agricultural interests would increase with the the add of water quantity. So we can obtain interest sharing contract of industry and agriculture: $\delta > p/(1-r_1)q$; $\eta = [(q-p) - qr_1]/(1-r_1)q > 0$.

As for cost allocation, owning to government and industry assume a shared responsibility of transfer cost, it becomes the second conflict in water rights transfer problem. Though we can't eliminate it, we can relieve it by changing income structure and improving both sides of contracts. In traditional mechanism, when $\psi \in [(0.6p - qr_1)/0.6p, (q - qr_1)/0.6p]$ both sides' benefits will increase along with the increase of in multi-agent cooperation, not influenced by parameter, to relief contradiction between the two sides. Meanwhile, considering to improve earnings, government and industry should abide by rules of cost allocation:

$$\phi > 1 - [(1-L_1)(C+\varepsilon) + (A_1 + A_2 + A_3 - A_1' - A_2' - A_3')]/C, \quad (67.9)$$

$$\eta > [q\Delta t(1-r_1) + (A_1 + A_2 + A_3 - A_1' - A_2' - A_3') - \varepsilon]/(1-r_1)q\Delta t. \quad (67.10)$$

(2) Indemnificatory contract

From the analysis of game model, we know that realization of game equilibrium solution is based on getting hold of related information and datas by every agent, including total regional water, variation tendency of water volume, water consumption situation and government policy and so on. Each agent will change the expected output if it is incomplete information or communication is not smooth, resulting in decision making bias. The government should promote to establish a communication mechanism of information and to provide a platform between each party of the transfer.

Certainly, on the one hand, because any variation in social-natural system will make agents' interest demand change, this rule of cooperation can get feedback from agents'information sets. On the other hand, it is possible to breach of contract or do not fulfill contract on time as the result of mind of risk aversion. If any agent don't keep to the contract, it would be terminated and all agents would go back to traditional mechanism to transfer water rights. In the end, comparing total incomes of two mechanisms: $P_2 - P_1 = A_{11} + A_{12} + A_{22} + (A_{31} + A_{32} - A_{31}' - A_{32}') > 0$, we learn that when adjusting water volume is fixed, regional total incomes will gain improvement with reduction of transaction costs.

67.5 Conclusion

This paper proposed a regional water resource allocation multi-agent game model with water rights transfer. Through the analysis of game model, we concluded a rule of multi-agent cooperation that can reduce transaction costs and increase net income of government and industry. The approach is applied to water rights transfer to illustrate the effectiveness of the proposed model. In contrast to previous studies, a kind of rule of multi-agent cooperation is considered in water rights transfer for ensuring the equity of water resource allocation, where often exists unfair phenomenon. To make all agents in RWRAP get more benefits, multi-agent' profit functions of game model are first introduced, and then Nash equilibrium solution can be obtained. To make better decisions, we applied the incentive contract and indemnificatory contract in cooperation mechanism.

The main contributions of this paper are as follows: firstly, this paper focused on the multi-agent game model about water rights transfer in RWRAP which has great practical significance. Secondly, the multi-agent cooperation mechanism about water rights transfer was considered for the first time, and the proposed model is closer to reality compared with traditional models. Finally, the game model was successfully applied to get cooperation rules of multi-agent cooperation mechanism, so that the model was proved to be viable and efficient. To develop more suitable models, future research may focus on more realistic factors, such as alternative water policy, water allocation in multiple stages and so on.

References

1. An S, Cui N, Hu Cb (2008) Simulation and analysis of route guidance strategy based on a multi-agent-game approach. In: Management Science and Engineering, 2008. ICMSE 2008. 15th Annual Conference Proceedings, International Conference on, IEEE, pp 140–146
2. Al-Radif A (1999) Integrated water resources management (IWRM): an approach to face the challenges of the next century and to avert future crises. Desalination 124(1):145–153
3. Asakura Y (1999) Evaluation of network reliability using stochastic user equilibrium. J Adv Transp 33(2):147–158
4. ESCAP Water Resources Series (2000) Principles and practices of water allocation among water-use sectors
5. Hoekstra AY (2014) Sustainable, efficient, and equitable water use: the three pillars under wise freshwater allocation. Wiley Interdiscip Rev: Water 1(1):31–40
6. Ma S, Bu J, Zhang A (2005) Game-based coordination method between system optimum anduser equilibrium in route guidance system. J Syst Eng 1:006
7. Osborne MJ, Rubinstein A (1994) A course in game theory. MIT Press, Cambridge
8. Read L, Madani K, Inanloo B (2014) Optimality versus stability in water resource allocation. J Environ Manag 133:343–354
9. Sechi GM, Zucca R (2015) Water resource allocation in critical scarcity conditions: a bankruptcy game approach. Water Res Manag 29(2):541–555
10. Shafie-Khah M, Catalão JP (2015) Multi-layer agent-based decision making model with incomplete information game theory to study the behavior of market participants for sustainability. In: 2015 48th Hawaii International Conference on System Sciences (HICSS), IEEE, pp 856–865

11. Tu Y, Zhou X et al (2015) Administrative and market-based allocation mechanism for regional water resources planning. Res Conserv Recycl 95:156–173
12. Wang Y, Li C, Fu Y (2003) A study of generalized shortest path arithmetic before trip based on utility theory. J Wuhan Univ Technol 5:032
13. Wang L, Fang L, Hipel KW (2008) Basin-wide cooperative water resources allocation. Eur J Op Res 190(3):798–817
14. Zhou Y, Guo S et al (2015) Integrated optimal allocation model for complex adaptive system of water resources management (II): Case study. J Hydrol 531:977–991

Chapter 68
Analysis on the Characteristics of Central Urban Area's Spatial Morphology and Its Cause of Formation in Big Cities

Yi Sheng and Leilei Li

Abstract Many scholars have come to the conclusion that the spatial form of the center city tend to be a circle in their research. We select more than 20 major cities of China, based on the map information and related data, and finally we verify that the spatial form of central urban area generally tends to be a circle, the decisive factor of which is the main oriented demand of all kinds of urban consumers, especially public services that keep business as its core attracting the urban subject to its close, thus forming a circular shape. Although there are traffic congestion and other issues of round cities, it is the form that can best conform to consumers' demands and has the highest operation efficiency.

Keywords Metropolis · Central urban area · Urban spatial morphology

68.1 Research Significance and Review of Related Literature

Large-scale urban space should include central urban areas, satellite cities and small or medium-sized cities which are directly radiated by it, while medium-scale urban space including central urban areas and satellite cities, and the small-scale urban space containing the central urban areas only. In this paper, the analysis of the large urban spatial morphology only is limited to the central urban areas.

Due to the fact that central urban areas of the big cities gather more than 70 % of the urban population and economy aggregate. Besides, urban problems such as traffic, ecological environment, slums are mainly reflected in the central urban areas. Therefore, choosing a reasonable spatial form has an important significance either

Y. Sheng (✉)
West 1st Section of Yihuan Road, Chengdu 610071, People's Republic of China
e-mail: shsh1999@sina.com

L. Li
Sichuan Academy of Social Sciences, Chengdu 610071, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_68

on overcoming the big city diseases to improve the operation efficiency of the city, or reducing the excessive urban construction.

There have been many achievements in the research of the spatial form of large cities. There are scholars using historical morphological methods, summing up that the urban city forms have concentric circle model, sector model and the multiple nuclei model; there are also scholars doing their research through empirical case and summing up that there are four kinds of growth model like axial growth model, concentric growth model, sector growth model and multi core growth model; and there are also scholars doing the research from the perspective of landscape ecology, inducing that there are three kinds of model including compact model, edge model and corridor model. No matter which method the analysis used, all point out the fact that the spatial morphology is a circular shape, and most of them think that the "circular city" is the ideal model [14]. Hoyte put forward the theory that the whole city was round in 1937. Lately, some scholars who use the compactness analysis method also conclude that the best space shape is presented as a circular shape [15]. In the research of concentric theory proposed by Burgess in 1923, the city is divided into five concentric circular regions like good residential district,business center zone, transition zone and workers' residential, and it is already achieved in some urban planning, which is all based on circular city theory.

Why today's big cities are not completely standard round? Because it is affected by many factors. The urban construction is affected by the law of traffic fluctuation (the development axis of the transport corridor), the optimization of urban land use, the rule of urban economic's agglomeration and diffusion and so on. there are some influencing factors as following:

Industrial upgrading factors: the upgrade from the industrial structure dominated by the traditional industries to the modern service industry is an important driving force for the evolution of urban spatial structure moving to a higher level. At the same time, a variety of production factors choose their best location affected by different agglomeration and diffusion mechanism, which promote the appearance of the new urban space function under the original urban spatial organization, and then new urban area and border zone emerge [5]. The influence of industrial development on urban spatial structure is mainly reflected in the scale of urban land use, land use structure, development direction, spatial pattern, land use layout and urban form. At the same time, the upgrading of the industrial structure can not be separated from urbanization effect such as spatial support effect, pull effect and carrier effect when the urban spatial form expand and urban development [4]. The suburbanization of traditional manufacturing industry is an important trend of the integration of urban spatial structure. From the practice of developed countries, the suburbanization of traditional manufacturing is usually close to the source of urban innovation, and this can help to acquire cutting-edge technology, to enhance the core capabilities of traditional manufacturing industry and to extend life cycle of industrial [13]. Large mechanize production organization mode led to the expansion of urban scale and the emergence of functional zoning and suburbanization, and ultimately form a multi center pattern. Flexible production organizations prompt the city form industrial clusters and high-tech park, and promote the continuous integration of each functional area of urban. the urban space has two trends both agglomeration and diffusion, spatial structure heterogeneity degree deepen [2].

Traffic factors: Guttenberg published papers in 1960 that reveal the relationship between accessibility of traffic facilities and urban development. With the growth of urban population, the city is bound to expand outward. This expansion is often sprawl outward, thereby reducing the efficiency of the operation of the city. Therefore, it is necessary to adjust the structure of the city, the mainly way is to establish a new center and improve transportation system. The reason why the city spatial structure presents types like the cluster, the star, the belt and the group is that the coming of the fast traffic mode. Due to the emergence and development of rapid transportation, non-equivalence of all kinds of land type is gradually leveled, making it possible that rapid transit construction can finance and area along the traffic line can construct [11].

Influence factors when city develop: at the growing stage, the city mostly grows like "extended-echo" type. When the city grows to a certain scale, especially when it becomes a metropolis, this model will lead to the "urban diseases", and then the "new town-collaborative" mode, namely focusing on building new city becomes the main way to open up new growth space [10].

The orientation of city constructure planning factors: aiming at solving the excessive city suburbanization and reducing public open space problems, they propose that we should construct compact urban space by moderately high density land development and multifunctional mixed development [12]. In accordance with the views of Nelson, urban growth management can be defined as "to use urban planning and regulations consciously, and use financial power of the state government and local government to influence the urban growth and development, and finally achieve the scheduled target" [9]. The policy tools include the overall planning, regional planning, subdivision planning, property taxes, development costs, infrastructure investment and other measures that have significant impact on land and housing construction. They intend to guide the development direction of the city to meet the three major standard goals including environmental friendly, financial and social equity to promote the construction of urban growing area [6], encourage the development of new district and the development of the built-up area, strengthen the investment of the neglected area, and distribute urban spatial index and partition control, etc. [3]. Combing all kinds of space resources like industrial function zone, industrial park, development zone, industrial base and professional industrial agglomeration area systematically. Identify different directions in the development of the industrial zone, and guide the scale of industry land use, the leading industry, spatial layout of industry and the area develop coordinately, make the positioning function clearly [8]. Metro-collaborative development strategy, that is, to break away from the original city and achieve the leaping development of the new city zone, form a comprehensive and independent new city, and can collaborate with the original city [10]. To build the "edge city" and high technology corridor, etc. [7]. In China we enact the law of "urban planning approach" since 2006 which introduces the concept of spatial governance zoning, in the central city level, requires to delimit the fields as forbidden construction area, restricted development zone, suitable construction area and build up area, and make out control measures of spatial development. Many studies confirmed that the driving forces of urban spatial expansion in China are affected by factors such as economy, transportation and policy (including planning guidance), which is the leading force of urban spatial expansion [1].

Research on urban spatial form has been one of the key and difficult points in urban research. We can make a conclusion from the above studies that industrial upgrading is the main driving force for the evolution of urban spatial. And the coming of rapid transit and the change of urban development concept all drive large cities to change from single center to multi center development, and policy and ecological environment are also part of the important factors. Because urban space formation and its evolution are influenced by many factors, especially the wide use of modern technology in the city, the form of urban space is becoming more and more complex. If we say the circular city is a typical morphology, then modern city come to new type of morphology such as the city develop along the traffic line and then spread into radial expansion and leap group expansion and so on. Whether its basic form will still be the circle needs further research.

68.2 Validation Based on the Central City Map and Related Data

This paper takes 25 representative cities of 31 provincial cities as the sample to investigate whether the basic form of the central city is round.

Our basic assumptions and methods as follows:

(1) The city is classified into three types, which are the plain cities along the river, the plain cities not along the river and the mountain cities along the river;
(2) Based on the map "Atlas of Chinese highway" issued by China Cartographic Publishing House in January 2015, on the map we draw a circle, and use the city administrative center, business center, transportation center or geometric center as the center of the circle.
(3) We set an area where have a certain population density or have contiguous buildings as the boundary, make the center of the circle as the center, take a radius value every 36 degrees and take 10 radius data altogether, remove the maximum value and the minimum value, and then calculates the average value;
(4) With average value as the radius to draw the circle, and then observe the built-up acreage of the city the circle contains;
(5) To determine whether the city is a circle or not by the proportion of the area occupied by the circle.

The proportion the build up area occupied by the circle of China's 25 main cities is as Tables 68.1, 68.2 and 68.3.

As we can see from the data in Tables 68.1, 68.2 and 68.3, apart from a handful of cities, for most of the 25 selected cities, acreage of the city in the circle contains 70 % of built-up area, some of them contains even more than 90 %. 82 % of the sample cities the acreage of the city in the circle contains more than 70 % of the

Table 68.1 The plain cities not along the the river (total 14)

Cities	Boundary (or Ring road)	Average radius (kilometer)	Acreage of the city the circle contains (square kilometers)	The built-up acreage of the city (square kilometers)	The proportion the build up area occupied by the circle (%)
Beijing	5th Ring road	13.53	574	750	76.53
Tianjin	3th Ring road	10.96	383	500	76.6
Shijiazhuang	3th Ring road	9.64	292	350	83.4
Taiyuan	Loop expressway	7.92	196.96	205	96.07
Shenyang	Loop expressway	10.38	338.31	500	67.6
Changchun	Loop expressway	5.7	102.01	222	45.95
Harbin	3th Ring road	10.08	319.04	360	88.61
Hefei	Loop expressway	6.72	141.79	263	53.91
Zhengzhou	Loop expressway	9	254.34	294	86.51
Chengdu	Loop expressway	12.5	490.62	600	81.67
Guiyang	Loop expressway	7	153.86	250	61.54
Kunming	3th Ring road	5.8	245	290	84.48
Xian	Loop expressway	11.7	429.83	450	95.51
Yinchuan	Loop expressway	5.04	79.76	111	71.86

built up area, and 44 % of the sample cities the circle contains more than 85 % of the built up area. Another phenomenon worth to be attended is that plain cities tend to be perfect circles, for example,cities in Chinese northern plains such as Beijing, Taiyuan, Zhengzhou, Shijiazhuang, Xi'an, and cities away from rivers in southern plains such as Chengdu, prone to expanding outward circularly. However, cities along large rivers such as Shanghai, Hangzhou, Nanchang, Wuhan usually develop strip-shaped along the river under the influence of topography, landscape, geomorphology and hydrogeologic conditions, resulting in a remote distance from perfect circles. But not all the cities along rivers are more slender than that in plain, for example, Chongqing, Nanjing Fuzhou are pretty close to standard circles.

Someone believes that the charm of cities is mainly formed by the effect of population density and population scale. The western evolution theory of urban spatial structure shows that the inherent factor affecting the urban space structure is social process such as economy, politics and culture, and the complex interpersonal social

Table 68.2 Plain cities along the river (total 10)

Cities	Boundary (or Ring road)	Average radius (kilometer)	Acreage of the city the circle contains (square kilometers)	The built-up acreage of the city (square kilometers)	The proportion the build up area occupied by the circle (%)
Shanghai		19	1133.54	1514	74.87
Nanjing	Loop expressway	12.03	454.42	608	74.67
Hangzhou	Loop expressway	10.45	342.89	551	62.23
Fuzhou	3th Ring road	6.7	140.95	177	79.63
Nanchang	Loop expressway	8.7	237.66	310	76.45
Jinan	2th Ring road	8.5	226.86	310	73.18
Wuhan	3th Ring road	12.63	500.88	700	71.42
Changsha	Loop expressway	9.7	295	380	77.63
Guangzhou	Loop expressway	11.3	400.95	637	62.94
Nanning	Loop expressway	7.5	176.62	240	73.3

Table 68.3 Mountain cities along the river (total 1)

Cities	Boundary (or Ring road)	Average radius (kilometer)	Acreage of the city the circle contains (square kilometers)	The built-up acreage of the city (square kilometers)	The proportion the build up area occupied by the circle (%)
Chongqin	Loop Expressway	8.8	243.16	269	87.46

relationship like economic, political, and cultural values are the fundamental reasons leading to social process. Accordingly, the research of urban spatial structure must be established on the theory of social relationships component, as well as the theory of spatial attributes of social process. Among these factors, economic development promote the evolution of urban spatial structure fundamentally by economic agglomeration, intensive economies, economies of scale and so on. But the reason why cities appear to be circles still needs to be proved and supported theoretically.

68.3 Analysis of Primarily Motivation of Cities to Be Circles

The crucial reason why city expanding outward in a concentric zone model is cites are affected by different demand of townsfolk, enterprise and the government.

Government, enterprise, leagues and residents are the major contributors of the city. But demand of the three contributors is not completely equivalent, even demand of each contributor is not really the same. In order to facilitate management and provide government services easily, governments at various levels, as the managers of city, often choose districts with compact population and commercial as their govern districts. Enterprise, affected by their operation contents, service objects and various demand of the environment, may need different urban functions, but they all generally prefer the location close to market and govern district, with convenient transportation, ancillary facilities and completed services for production and living. Besides, closing to consumers is also a special demand of commercial enterprises. Having a close relationship with government and enterprises, leagues may desire to be around with government and residents. Residents with complicated constitutions and easily influenced by the income levels, job orientation and living demands, may need more different city functions, but their fundamental need is almost the same, not only near with commercial, education and cultural centre but also with leagues, govern districts and the company they work for. Although these complex motivations implies that the major contributors have intentions to assembling and city inevitable develop compactly. But the combination of these motivations are not enough to illustrate city will be promoted to be circular.

Therefore, the main demand of the circular city development should be located among all these demand, so should the reason why to format a powerful centripetal force in the geographical center, making the subject moves closer to the center even at a higher cost. When we analyze of the needs of the main body, we find that the main demand is the aggregate of industrial and commercial service enterprises, which causes the agglomeration of the government and residents and this is the initial cause of the city's rise. The formation and development of Industrial and commercial areas promote the city's employment and consumption, thus becoming the main driving force of agglomeration. The city center which has a minimum distance to other area of the city, the most convenient transportation and the most extensive range of services will bring together a large number of people here to work and life. With the expansion of city scale, the center city land becomes more and more expensive. Cost oriented industrial enterprises that close to the needs of the consumers are gradually close to the lowest cost location instead, industrial enterprises forced to leave the regional center naturally under the influence of traffic. In spite of this, it will always at the nearest location away from the center, hoping to find a balance between the cost and the demand. The desire to the center will not lose. why mega cities also have this tendency, is because that the business area is larger and larger, service quality is getting higher and higher, and promoting the development of quality education, health, culture and other services, stimulating the formation of convenient transportation network, promoting the center of the city have the most convenient service facilities and the service, which will improve the modernization level, improve the life quality of residents, and also improve the government public service. And the closer to the central part, the greater of the density of the business services, social services and public services, the more we can select, the higher the service quality will be. Thus the residents tend to live closer to the center. It is the mutual promotion of residents, business, education, medical treatment, culture and government services which constitute the inevitable pattern of urban circular development.

Of course, cities in real world, just as the 25 ones we have verified are not all perfect circles, their shapes are affected by many factors based on circles.

The first factor is the traffic. Limited by geographical conditions and new area developed by the government, city may build fast transportation to promote the outward expansion. So it seems impacted by rivers that make city stretch by the direction of traffic, circular city becomes a ellipse one gradually. Despite all this, there will be several dense centers on the traffic axis. If the economic benefit of vertical development is lower than the transverse one, the transverse connection will be strengthened among all the transits outward radiation. Ultimately, city look like a regiment. Enterprises and residents develop around the center closely and finally form a circular district. Traffics built according circular links will reinforce the tendency of city to be circular, that is the phenomenon we criticized "urban overspreading".

The second is the division of rivers. Developing around the river is an important characteristic of city with rivers across by because of the high cost to be circular. Even so, there will be several regiments around the rivers, each district still will be a circle. At the same time, high efficiency generated by city aggregation especially the attraction produced by the center of circle, will promote every district to move close to the center. Building its bridges, subways and under-river tunnels, city can modernize its infrastructure. Traffic artery will move to the hinterland of the district with the development of traffic, the whole city will be a circle at last. So city with several districts would still be a circle if observed in a greater geographical scope.

The third factor is the attraction of government. Where the government choose to be their office will be a great influence on the shape of the city during its evolution. Government is usually the center of all contributors especially under the current system. We can expound from the following two aspects: on one hand, government with more available resources can attract many contributors approaching and form denser population and commerce. Corresponding, education, culture and health care resources move toward the government so that the overall benefits of agglomeration will be strengthened continuously. On the other hand, government have attractions for all other urban contributors, so it can change the status quo by projecting the layout of urban space and even promote the movement of commercial and residential areas by migrating their office.

References

1. Chen J (2009) Analysis on the causes of urban sprawl in China. Discussion on Modern Economy (4) (in Chinese)
2. Chen L, Cao R (2007) The influence of the mode of production organization on the evolution of urban spatial structure. J Nanjing Univ Technol (Soc Sci Edit) 1:80–84 (in Chinese)
3. Diao L (2010) Analysis of the effect mechanism of urban space reconstruction on economic growth in china. China's Popul Resour Environ 5:87–94 (In Chinese)
4. Dong W, Deng F (2011) The evolution characteristics and spatial effect of the resource based industries in urumqi. Geogr Res 4:723–733 (in Chinese)
5. Fan X, Wang Z (2015) Enterprise, industry agglomeration and city spatial structure evolution-theory and dynamic analysis of the new economic geography perspective. J Southwest Univ Natl (Humanit Soc Sci) 1:136–144 (in Chinese)
6. Guo X (2009) Policy practice of urban growth management in the united states and its enlightenment. Planner 8:20–25 (in Chinese)
7. Knox PL (1991) The restless urban landscape: economic and sociocultural change and the transformation of metropolitan. Annal Assoc Am Geogr 81(2):181–209
8. Kong L (2013) Smart growth in urban space based on the perspective of new urbanization. J Zhongzhou 7:27–31 (in Chinese)
9. Nelson AC, Pendall R et al (2002) The link between growth management and housing affordability: the brooking in stitution center on urban and met-ropolitan policy, pp 117–158
10. Wang J (2013) The pattern of space of big city development - based on the morphological evolution of Ji'nan city as an example. Urban Dev Res 7:90–96 (in Chinese)
11. Wang X (2010) Reorganization and adjustment of urban spatial structure in the development of rapid transit. J Zhongzhou 2:69–71 (in Chinese)
12. Wang Z (2014) Study on spatial structure optimization of urban new area based on smart growth: a case study of tianjin binhai new area. Reg Res Dev 8:90–95 (in Chinese)
13. Zhang M (2003) industrial agglomeration, new industrial district and urban economic spatial integration. Chin Soft Sci 7:119–124 (in Chinese)
14. Zhang R, Zhang X (2012) Research progress and reiew of urban spatial expansion. Forum Sci Technol China 8:151–155 (in Chinese)
15. Zhong H (2010) Study on the spatial form of the main urban area of Chongqing city. Master's thesis, Southwestern University (in Chinese)

Chapter 69
Information–Analytical Technologies of Decision Support in Management of Power Systems

Shavkat Ayupov and Abdulla Arifjanov

Abstract In market conditions the effective control of the operation of power systems is directly dependent on the implementation of management decisions. Management decisions in turn depend on whether, what information (volume and quality) comes, how it is processed and used. In the coming decades the relevance of this problem will grow since information becomes the main strategic resource in the competitive struggle. In this regard it becomes topical the problems associated with the unification of territorially distributed facilities power systems into a single information space, which provides: integrated view of the complex control object as a whole; a comprehensive analysis of the collected information about him; the extraction from the huge volume of detailed data some useful information-knowledge about the regularities of its development. Solving these problems is possible by introduction in the practice of modern information and intelligent decision making support technology. In the basis of these technologies are the automated information–analytical systems (IAS) for the collection, storage systematization, processing, analysis and presentation of information. This report is dedicated of the new information–analytical technologies, allowing automating the management of energy efficiency in enterprises. For disclosure essence of information–analytical system of support for management decision-making is considered a formal model of control process. Considered issues of the designing of structure and semantics of the data to form a data warehouse of the information–analytical system for decisions support in Management with the use of a balanced scorecard.

S. Ayupov
Institute of Mathematics, Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan

A. Arifjanov (✉)
Institute of Energy and Automation, Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan
e-mail: arifjanov@yandex.ru

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_69

Keywords Effective control of the operation of power systems · Management decisions · Modern information and intelligent decision making support technology · Information–analytical technologies · Formal model of control process · Balanced scorecard

69.1 Introduction

Political, social and economic transformations that have occurred in recent years in the world require a change in approach to the management of the country, the economic sector, the industrial enterprise, the socio-economic sphere, etc. Over the past 10 years, the volume, content and quality of business information has changed more than for the preceding 70 years. In market terms effective management is directly dependent what information (by volume and quality) is supplied, how it is processed and used. In the coming decades the urgency of this problem will grow because the information is becoming a major strategic resource in the competitive struggle. The primary role in solving indicated problems is given an information technology (IT), which ensures support of the management activities [9].

Despite of the active development of the IT and ubiquitously their introduction in the management, majority of the enterprises, seeking one way or another to automate the management, get ended up aggregate of disparate and sufficiently of powerful automated information systems (AIS). The reality is that, the process of "a scrappy" of automation in large companies has led to the fact that in a multitude of divisions are applied does not fit with one another program-application. As a result, the movement of information flows in companies is hampered, and this, in turn, makes difficult of realization not only of the monitoring of action of divisions, but also reduces the effectiveness of their activities [1].

With the growth of enterprises and the development of the network of branches always a problem of analysis of activity of the various divisions, as well as the control and planning of activity of the company as a whole. But all the information necessary for the analysis and management decision-making exists, but, unfortunately, it is scattered by various local systems, are collected in the interest of the separate structures and for complex analysis in the interest of the enterprise as a whole are not available.

The absence of a unified technical policy in the deployment of departmental systems has led to the fact that the information in them is not coordinated and does not accumulate, although analysis of its dynamics is extremely important for decision-making on the management of objects. In this regard it becomes topical the problems associated with the unification of territorially distributed facilities power systems into a single information space, which provides:

- integrated view of the complex control object as a whole;
- a comprehensive analysis of the collected information about him;
- the extraction from the huge volume of detailed data some useful information—knowledge about the regularities of its development.

Solving these problems is possible by introduction in the practice of modern information and intelligent decision making support technology [2, 3].

69.2 Substantiation of Necessity the Application of Information–Analytical Technologies in Management

Increase of the tempos and the scale of production, improving of the quality of products is now insufficient to achieve a competitive advantage in the market, so many businesses are switching to the new progressive methods of corporate management allowing to timely respond to changing market conditions. For effective management by systemic-complex object, which is of the modern enterprise, is required, above all, the creation of schemes of work with the information as the structure of the interaction of control system with the object. This structure should allow the accumulation and use of meta-information to make controlling decisions [3].

Traditional approaches to data collection and analysis in power systems are scant basis for deep analysis, as to find answers to the questions "how" or "why", as well as to determine the most effective actions for their wider implementation [5]. Existing methods of data analysis and processing of information is absolutely not enough to a detailed analysis of impact specific actions for to improve energy efficiency and better energy management. Even if it is possible to organize a total collection of data about energy consumption—this will not be enough. The obtained measurements require deep analytical processing and analysis. First of all, for the development of administrative decisions, necessary to identify the causes of ("Why is this happening?"), which led to those data, obtained of the accounting systems energy consumption. At that, the sought the reasons can be outside control of energy metering systems [8]:

- in the characteristics and modes of use of technological and auxiliary equipment;
- in the environment parameters;
- in the qualification of management and production personnel;
- in implementing improvements and reconstructions;
- in many other areas, where with energy metering devices are not measured or cannot be measured in principle.

The goal and tasks of management of any enterprise are defined by its strategy, i.e. any control should be aimed at achieving the strategy of the enterprise. Therefore, special attention is given by the strategic management. Research in this area led to the appearance of new paradigms, concepts and tools of management [2, 5].

For solve of problem get away from disparate AIS and transition to a unified platform management of enterprise, must be created information systems of management of the enterprise, which allow to automate the management processes in main areas of activity and levels management of enterprise.

Creating such a structure is connected with the investigation of principally new ways of creation of management systems based on the new information and analytical technologies that enable optimally to organize activities in the changing market conditions. Use of outdated methods and means hinders the transition of economic management system on the new organizational forms and urgently requires searching of the innovative ways development.

Solution of these problems is seen in the development of comprehensive information management systems that provide a comprehensive analytical processing of the integrated retrospective and operating information for decision making [2, 5]. By such systems are information–analytical decisions support systems (IADSS) in management which are based on the achievements of modern information and communication technologies (Fig. 69.1).

69.3 Problems of Creation of Information–Analytical Systems (IAS)

Management objects, for which are realized large-scale projects to create modern IAS, are characterized, as a rule, a number of features, including [2, 5]:

- structural complexity (multi-level hierarchical structure of the organization) and territorial distributivity;
- functional complexity (multi-level hierarchy and a large number of functions performed by the organization);
- information complexity (large number of sources and consumers of information (ministries and agencies, local authorities, partner organizations), a variety of forms and formats for submission of information complex information model of the object—a large number of information entities and complex interactions between them), a complicated technique of passing documents;
- complex dynamic behavior, due to the high variability of the external environment (changes in legislation and regulation, instability of economy and politics) and internal environment (reorganization, turnover).

These features of the objects of the introduction of IAS cause along with an extremely large amount of data in Data Warehouses (DW), and their essential heterogeneity. In such circumstances, ensuring the adequacy and completeness of the information analyzed for decision adequate to the real condition of object of management decisions, is a major problem in the creation of an effective IAS [3, 4]. Because the pile DW IAS information not relating to the subject area and the objectives of strategic management control, dramatically reduces its effectiveness. Therefore the priority for the establishment of IAS is the definition of mandated targets, the composition and structure of the data, allowing to solve these tasks and the development of its information model.

Today, in most cases, the design of the IAS is based on the principle “What you want?” not “What should be?”. Since the main on the value of IAS is to support decision making in enterprise management, natural in the analysis of data in

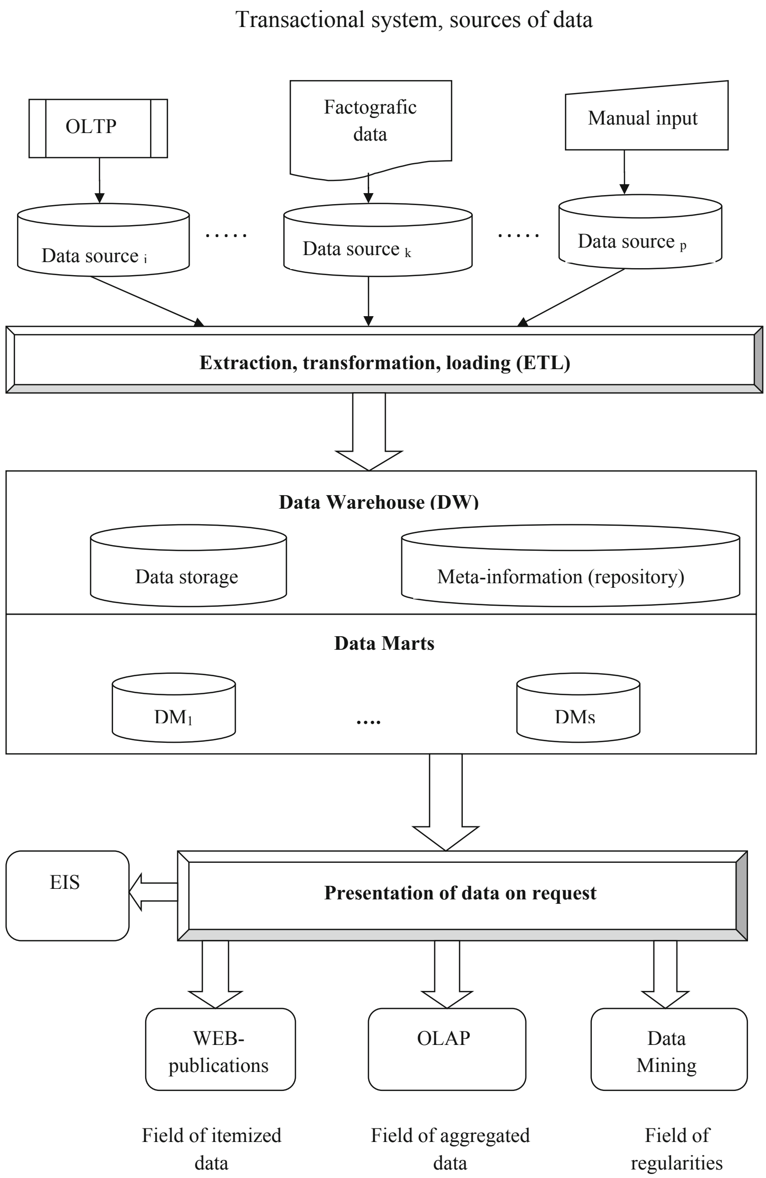


Fig. 69.1 Structural scheme of information–analytical decisions support systems

the system needs to be performance indicators strategic and tactical plans of the enterprise. But to establish measurable indicators that reflect a causal connection between the operational and strategic goals of the enterprise is not always possible.

69.4 The Approach to the Creation of Information–Analytical Systems Using the Balanced Scorecard

Today in the solution of this problem the most promising is proposed by Kaplan and Norton approach based on the balanced scorecard (BSC) [12] that define the structure and semantics of data to form a Data Warehouse and develop Business Intelligence (BI) applications, which in recent years has turned into a full-featured custom applications. Outgrown the bounds of conventional appraisal system, BSC has provided a new approach to the strategic management of companies of any complexity operating in different industries. Kaplan and Norton have proposed a system based on cause-and-effect relationships between strategic objectives that reflect their parameters and factors of achieving planned results. It consists of four components—financial, customer, internal business processes and learning and staff development, goals and objectives which impact financial and non-financial indicators.

Basic adjustment of the concept of balanced scorecard is that traditional financial and economic indicators are insufficient for determining the strategic success of the enterprise and provide feedback. To solve these problems, it is necessary to have a more "balanced" set of indicators of enterprise activity in various planes, allowing the control of the factors influencing these indicators, not just track results. For successful monitoring of progress in achieving strategic goals should not all the attention should be concentrated on the evaluation of past performance. It is necessary to consider the indicators that will affect the company's results in the future [11].

The key idea, proposed by Norton and Kaplan, was to review the activities of the company as a whole from four different points of view–perspectives: financial, customer, internal business processes and learning and development, within which are the goals of the company [12]. The allocation of such perspectives is obvious and understandable internal logic: the better the enterprise is the case with the qualified staff and technologies (developmental perspective), the easier it is to maintain the efficiency of internal business processes of the enterprise. This in turn contributes to an organization of production that meets the interests of suppliers and subcontractors, and also contributes to the production of quality products that meet the requirements of buyers. All this helps to achieve its financial plans, including revenue, profit and cash flow.

Thus, based on the methodology of BSC–formalize strategy of enterprise, in the form of a strategy map, which contains about 20–30 objectives grouped by perspectives. These objectives should clearly state the patterns of development of the enterprise. Between the objectives need to be formalized causal relationships, allowing to localize the search for possible problems in the implementation of the development as a whole, and gave a vivid dynamic picture of implementation of all measures [12].

The BSC approach from the beginning defines the business aspects of analyzed data that allows you to design analysis information system top-down in parallel with the introduction of the company MBO (Management by objectives–management based on the achievement of the objectives). Instead of exclusively retrospective-governmental financial metrics, in data warehouses, based on the BSC approach, will be considered “leading indicators”, al-lowing to predict changes in the business. Such storage will provide analysts with a complete picture of the development of the enterprise, at least in four areas [6, 10, 12]:

- financial direction, considering the efficiency from the point of view of return on investment
- marketing direction, including assessment of usefulness of goods and services from the point of view of the end consumer
- organizational and technological direction, evaluates internal operational efficiency and effectiveness of the organization’s business processes
- direction of innovation and learning, revealing the capacity for constant improvement and new ideas.

To reveal the essence of information–analytical systems of support of acceptance of administrative solutions (IAS DS) consider a formal model management process.

The process control as an organization of purposeful influence on the object can be implemented by a two-stage scheme [9]:

$$\mathrm{A} \longrightarrow \mathrm{Z} \longrightarrow \mathrm{U}.$$

At the first stage according to the needs A and the condition of the external environment X is defined the purpose of management Z:

$$\mathrm{Z} = \varphi_1(\mathrm{X}, \mathrm{A}),$$

where φ_1 is a algorithm synthesis of management purpose Z. This task is solved on an intuitive level.

At the second stage is determined the control (controlling action) $\mathrm{U_x}$, the implementation of which ensures the achievement of the purpose Z, generated in the first stage, which leads to the satisfaction of the subject. It is at this stage can be used all the power of the formal apparatus, by which on the purpose Z is synthesized control $\mathrm{U_x}$.

$$\mathrm{U}_x = \varphi_2\,(\mathrm{Z}, \mathrm{X})\,,$$

where φ_2 is the control algorithm. This algorithm is the subject of decision making in management by any object.

Thus, the separation of the management process into two stages reflects known science-informal (intuitive expertise) and formal—algorithmically. If until first is fully owned by the person, the second is the object of the application of formal approaches. Naturally, these various functions are performed by different structural elements. The first function (φ_1, executes the subject, and the second (φ_2 is control device). The control system performs the function of management objectives Z generated by the subject.

The main task in making management decisions is selecting the best alternative providing achieve certain goals, the existing constraints or ranking of many possible alternatives for degree-nor their impact on the achievement of this goal. To solve this main problem, it is first necessary to solve the nontrivial problem of multiple criteria evaluation of alternatives. Selection criteria assessment of achievement of that goal (alternative solutions) is a complex task. To solve this problem can be used, in particular, the approach of decomposition of the main goal to the level of detail when a lower level of a hierarchy of objectives you can formulate criteria that enable to adequately describe the degree of achievement of objectives in the adoption of any alternative, that is, for each level must be defined goals and measuring their performance. First we defined the main strategic goal. Is further decomposed into sub-objectives [1–3, 6].

To ensure the decision-making process for the proposed scheme are adequate and sufficient information necessary for effective instrumentation. These tools are key performance indicators (KPI) and the balanced scorecard, widely spread in management practices in Western companies [6, 7, 12]. KPI is a set of core indicators describing the achievement and the efficiency of the company. Under the KPI system is a system of financial I_f and non-financial I_{nf} indicators influencing the quantitative or qualitative change of results in relation to strategic objectives (or expected results)

$$\mathrm{KPI} = \{\mathrm{I_f}, \mathrm{I_{nf}}\}, \tag{69.1}$$

KPI are quantitative indicators to measure critical success factors, expressed in numerical form. When forming indicators, it is necessary to concentrate on the most essential of them, cutting off all secondary, reducing their number to the so-called “key”. The number of KPI should be limited (to insure their implementation and to ensure the required quality of monitoring).

The balanced scorecard includes KPI required for each jth object control (manufacturing or business subdivision), and the methods of their evaluation

$$\mathrm{BSC} = \{\mathrm{KPI_{ij}}, \mathrm{O_j}\}, \quad \mathrm{i} = 1, \ldots, \mathrm{N}, \quad \mathrm{j} = 1, \ldots, \mathrm{M}, \tag{69.2}$$

where N is the number of KPI, M—number of control objects.

These systems or techniques make a basis at decision-making, are based on an assessment of efficiency of activity of the enterprise and are directed on achievement of strategic objectives of the organization.

The assessment of efficiency is the tool which allows to define as far as management of the organization corresponds to the level of achievement of strategic objectives. This tool facilitates process of adoption of administrative decisions due to providing the person making the decision full information and allows to identify the fact and area of emergence of a problem.

Why it is about the management founded on efficiency? Accumulation of rates and scales of production, improvement of quality of production are already insufficient for achievement of competitive advantage now in the market and therefore many companies pass to new progressive methods of corporate management. These methods allow to react in due time to change of conditions in the market, and foreign firms successfully apply them.

The problem of system of KPI and the balanced indicators consists in transfer of strategy of the company S to the complex set of indicators of its activity {I} determining key parameters of system of measurement P_m and controls P_c

$$\mathrm{BSC} : \mathrm{S}\,\{\mathrm{I}\} = \{\mathrm{P_m}, \mathrm{P_c}\}. \tag{69.3}$$

The set of indicators sets a basis for formation of strategy of the enterprise and includes quantitative characteristics for informing employees on major factors of success in the present and the future.

Formulating the expected results, the enterprise sets the purpose and creates conditions for its realization, and the top management directs energy, abilities and knowledge of employees on the solution of problems of a long-term outlook.

Basic installation of the concept of the balanced indicators consists that traditional financial and economic indicators are insufficient for definition of strategic success of the company and providing feedback. For the solution of these tasks it is necessary to have more “balanced” set of indicators of activity of the company in various planes allowing to control the factors influencing these indicators, but it isn’t simple to trace results. For successful monitoring of progress in achievement of strategic objectives it isn’t necessary to focus all attention on an assessment only of last activity. It is necessary to consider also those indicators which will influence results of the company in the future.

The reference point on the indicators characterizing only one sphere of activity can negatively be reflected in the end result. Therefore the system of the balanced indicators includes four main aspects which are in a complex characterizing any manufacturing enterprise:

- Financial activity—aspect “Finance”;
- The relations with the consumer—aspect “Market”;
- Internal production activity aspect “Production”;
- Training and development—aspect “Shots and an innovation”.

The BSC is a set of the interconnected purposes (tasks) and indicators estimating them

$$\text{BSC: PURPOSES (TASKS)} \rightarrow \text{INDICATORS} \rightarrow \text{MEASUREMENTS.} \tag{69.4}$$

Arrangement of target (planned) values of indicators means their subsequent measurement and the accounting of actually reached results. Then can be corrected both target values of indicators (plans), and structure of the purposes and indicators (strategy). Schematically it is shown in Fig. 69.2.

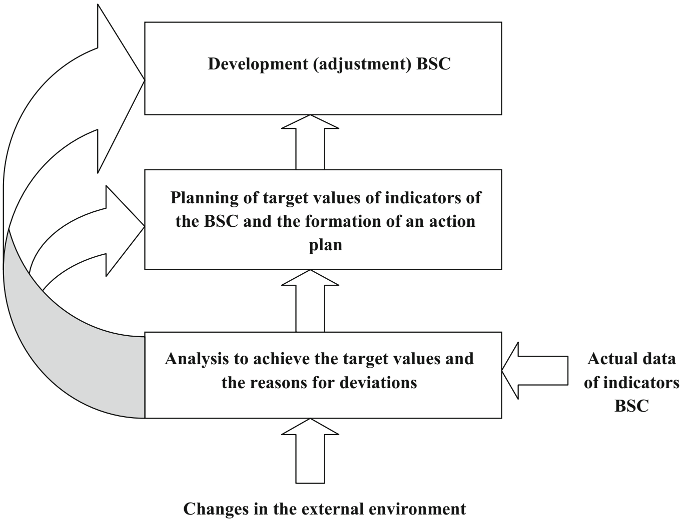


Fig. 69.2 Basic scheme of the concept of the balanced indicators

If to say that the BSC is strategy formalization, the mechanism described above is that other, as the closed cycle at the strategic level of management. And the set of the used indicators defines system of strategic management accounting. The structure of the balanced scorecard is shown in Fig. 69.3.

Theoretically KPI indicators in the BSC can be detailed until they don't capture all indicators used in traditional management accounting. But in reality of it doesn't occur as specification of KPI is usually limited to the level of departments/processes owing to labor input of its development and the subsequent use. On the other side

$$\text{EMS} := \{\text{STRATEGY} \rightarrow \text{BSC} \rightarrow \text{PURPOSES} \rightarrow \text{INDICATORS} \rightarrow \text{MEASURMENTS} \rightarrow \text{SUBSYSTEMS}\}.$$

Fig. 69.3 The structure of the balanced scorecard of a task at management accounting and at the balanced system of indicators are various: the first is necessary for daily monitoring of operational activity, and the second is for periodic control of following to the chosen strategy.

BSC is a link between subsystems of management, a peculiar uniting control. If the task of creation of a enterprise management system is set (EMS), it is necessary to begin with strategy, then BSC, but only after that—other subsystems of management:

$$\begin{aligned}\text{EMS} :=& \{\text{STRATEGY} \rightarrow \text{ BSC } \rightarrow \text{ PURPOSES} \rightarrow \text{INDICATORS} \\ &\rightarrow \text{MEASURMENTS} \rightarrow \text{SUBSYSTEMS}\}.\end{aligned}$$

Design of information and analytical systems on the basis of the BSC is carried out in two stages [6, 7]:

(1) Design of the card of strategy—its graphic description in the form of a set of relation-ships of cause and effect. For each prospect (finance, marketing, technologies, innovations) strategic objectives have to be defined and the tree of the purposes is constructed.
(2) Definition KPI (Key Performance Indicator), numerical characteristics of the chosen purposes (metrics which need to be collected in storage of data). In fact, these metrics set structure of data in storage.

It is necessary to distinguish KPI of the top and lower level. Has to contain in storage of data both information for strategic management, and detailed data on the basis of which this information was received to provide possibility of transition from strategic objectives to actual data which stand behind these purposes. Such transition (drill-down-descent by data) in information and analytical system is realized by means of the OLAP-tools realizing multidimensional (and at the same time multilevel) data presentation.

Design of multidimensional data presentation begins with formation of the card of measurements. For example, in the analysis of sale of products can be expedient to allocate the separate parts of the market (developing stable, large and small consumers, probability of appearance of new consumers, etc.) and to estimate sales volumes on products, territories, buyers, segments of the market, sales channels and the sizes of orders. These directions form a coordinate grid of multidimensional representation of sale—structure of its measurements.

As the activities of any enterprise takes place in time, the first question that arises when analyzing is the question of the dynamics of development of business. Proper organization of the time axis will allow qualitatively to answer this question. To analyze the effectiveness of the divisions should establish its measurement.

It is important to distinguish values of KPI in the set coordinate grid from actually KPI (for example, the number of transactions is the indicator characterizing operational activity of the enterprise, and the number of transactions in the set region for last month is a value of this KPI).

69.5 Conclusion

The problem of creating effective systems for strategic management of major energy companies and enterprises are one of the most pressing at the present time. It is caused that the success of any company or enterprise today is largely determined by the quality of its management system. It should provide the achievement of strategic goals through the solving current problems, provide of managers at all levels timely, complete and accurate information needed to make economically justified managerial decisions.

Solution of this problem is seen in the development of comprehensive information management systems that provide a comprehensive analytical processing of the integrated retrospective and operating information for decision making. By such systems are information–analytical decisions support systems (IADSS) in management which are based on the achievements of modern information and communication technologies.

These features of the objects of the introduction of IAS cause along with an extremely large amount of data in Data Warehouses, and their essential heterogeneity. In such circumstances, ensuring the adequacy and completeness of the information analyzed for decision adequate to the real condition of object of management decisions, is a major problem in the creation of an effective IAS. Because the pile DW IAS information not relating to the subject area and the objectives of strategic management control, dramatically reduces its effectiveness. Therefore the priority for the establishment of IAS is the definition of mandated targets, the composition and structure of the data, allowing to solve these tasks and the development of its information model.

In designing of information–analytical systems today a perspective is a business-oriented approach, based on the BSC (Balanced Scorecard). BSC approach from the outset defines the business aspects of the analyzed data that allows you to design information–analytical system from top to bottom in parallel with the implementation in the company MBO.

References

1. Arifjanov A (2007) System approach to the creation of corporate information—analytical systems. J World Comput Autom 2007(4):75–77
2. Arifjanov A (2009) Information-analytical system of decision support in the management of the real sector of the economy: problems of creating and ways of solving. J Probl Inf Energy 12(5):11–24 (in Chinese)
3. Arifjanov A (2009) Problems of formation of a coherent information base of information-analytical system. In: Proceedings of the international scientific-practical conference "actual problems of mathematics, computer science, mechanics and control theory", pp 254–260
4. Arifjanov A (2010) Problems of modeling the subject area in the design of information-analytical systems. In: Proceedings of the Kyrgyz National Technical University, Bishkek, pp 124–128

5. Arifjanov A (2011) Information-analytical decision support system in the management of complex objects. In: Reports of the seventh Asian international school-seminar “optimisation problems of complex systems”, Tashkent, pp 138–154
6. Arifjanov A (2011) Designing of corporate information-analytical system based on the balanced scorecard. J Probl Comput Sci Energy 5(5):50–68 (in Chinese)
7. Arifjanov A (2014) Analysis and synthesis of of information support of information-analytical systems using balanced scorecard. In: The international conference on advanced mathematics, computations and applications (AMCA’14), pp 8–11
8. Arifjanov A (2015) Forecasting and rationalization of energy consumption for megacities taking into account the factors caused by scientific and technical progress, with application of informational - analytical technologies. The global forum for energy, environment and commercial civilization (GFEECC). Sichuan University, China, Chengdu, pp 22–26
9. Arifjanov A, Kabulov V (2006) The system approach to problems of automation and information. In: Proceedings of fourth world conference on intelligent systems for industrial automation (WCIS-2006), pp 22–27, Kaufering (Germany, b-Quadrat Verlag)
10. Arifjanov A, Nabiev O (2008) Information-analytical technology of enterprise management using balanced scorecard. J Probl Inf Energy 120(5):3–10
11. Kaplan R, Norton D (2005) Strategic maps: transformation of intangible assets into tangible results. Olympus-Business
12. Kaplan R, Norton D (2006) Balanced scorecard. From strategy to action. Moskou, Olympus-Business

Part V
Computing Methodology

Chapter 70
E-Procurement Platform Implementation Feasibility Study and Challenges: A Practical Approach in Iran

Meysam Maleki, Mahmoud Karimi, Haniyeh Reyan and Virgilio Cruz-Machado

Abstract The current research investigates implementation feasibility and challenges of e-procurement platform in Iran. In order to do so, it reviews the literature regarding e-procurement implementation challenges in general. Thereafter it looks into key important figures which have direct or indirect influence of the success of this platform. Indicators such as population age, population distribution and number of internet users are discussed to support the hypothesis that Iran presents strong potential for an e-procurement platform. The literature review indicates most of implementation challenges are similar to those reported in other countries, however there is a few critical national factors which are identical to Iran. Analysis of key figures proves although the environment seems to be ready and it is feasible to implement an e-procurement platform, challenges have to be considered and solutions to deal with them should be planned in advance.

Keywords E-procurement · E-sourcing · E-business · Tender · B2B

70.1 Introduction

On the early 1990s a new technological approach of conducting business emerged called e-business that quickly took over the traditional approach of commerce with more sophisticated and developed means. E-business covers different ways of

M. Maleki (✉) · V. Cruz-Machado
UNIDEMI, Faculty of Science and Technology, Universidade Nova de Lisboa, 2829-516 Lisbon, Portugal
e-mail: maleki@fct.unl.pt

M. Karimi
Simorgh Investment Group, 1947875353 Tehran, Iran

H. Reyan
Arian Saeed Industrial Group Incorporation, 1947875353 Tehran, Iran

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_70

managing a business using electronic devices or channels. Initially the e-business was mostly focused on the Business-to-Consumer (B2C) relations where a seller is introducing a product/service by internet which could include the e-payment as well. However, the B2C experience gradually got expanded to the Business-to-Business (B2B) zone where businesses manage their mutual transactions through electronic platforms. Nowadays, suppliers in B2B relationships are confronting a new environment in which their interactions with customers are increasingly being shaped by IT-based procurement management tools. However, the wide spread use of electronic commerce in B2C still falls short of reaching the tipping point in the B2B in many countries.

Electronic procurement (e-procurement) is an offshoot of e-business in a B2B environment which is emerged from the adoption of the Internet by businesses. Due to the fact that e-procurement takes place on an internet based platform, the accessibility of internet and familiarity of business in using this tool plays critical role in application level of this platform. Therefore, successful e-procurement platforms are operating mostly in developed countries where the infrastructure is ready, business present less resistance, work flow are settled, legal frameworks are available, etc. Thus, there are different challenges in the business environments where there is no history of an e-procurement platform. The literature indicates that some of such challenges are similar in different countries, while there are also some challenges identical to each specific country.

The current research takes a practical approach to explore the implementation challenges of an e-procurement platform in general in the literature review section. The discussion section, aligns the literature with the national characteristics of Iran and studies the feasibility of implementing such platform regarding Iran's historical and demographical status.

70.2 E-Procurement Literature Review

In the third millennium there is a growing interest to boost the use of electronic communications to deal with B2C, B2B or Administration-to-Administration (A2A) relations. Initially it was focused in the B2C environment, whereas currently many B2B and A2A relations are also managed through electronic communication channels. The current research looks into e-procurement which is under B2B relations.

The term e-procurement refers to the use of electronic communications to deal with business process between sellers and buyers. In other words, it can be defined as the B2B purchase and sale of supplies over the internet. This approach can be found in a variety of ways from public marketplaces involving many firms to private exchanges that are currently facing a challenging environment to migrate from paper-based systems to an electronic ecosystem. Nevertheless, e-procurement as a new trend faces several interlinked challenges such as lack of interoperable, privacy and provenance of data and information, lack of transparency [3].

Table 70.1 Supply side and buy side solutions

Supply side		Buy side
e-commerce solutions	Tender	e-sourcing solutions
	+	
1. Market intelligence	Order	1. Demand management
2. Brand management	+	2. Auctions
3. Promotions management	Invoice	3. Suppliers management
4. Sales management	+	4. Contract management
	Payment	

An e-procurement platform has two players as the buyer and supplier. Each play uses specific solutions with respect to its business purpose. The buyers employ e-sourcing solutions such as demand management, auctions, suppliers' management, and contract management. Whereas the suppliers use e-commerce solutions namely market intelligence, brand management, promotions management, and sales management (Table 70.1). It is clear that both players engage in some solutions such as contract management, however, in practice, the buyer put on its buy list and specifications then sellers propose their bid. Therefore, the contract management falls on the buyer side.

E-procurement as a business platform can be employed by both private and public sector. However, each of these sectors require they specific work flow as well as legal procedures. Vaidya and Campbell [12] worked in application of e-procurement in the public sector which requires more legal and legislation dimensions in addition to what is considered in the private sector. In another research, Yu et al. [14] studied application of e-procurement solution on maintenance, repair, and operating goods which showed positive influence of organizational acceptance on its performance.

An e-procurement platform manages the whole business procedure on an electronic communication channel. Therefore, it requires to include wide range of fields such as attestation, tender management, noticing, evaluation, and contract. Figure 70.1 illustrates the general scenario happening in an e-procurement plat form. It is initiated by the e-attestation including online user registration, profiles management, library of attestation documents, and collection of qualification data from users. And the procedure closed by e-contract which contains contract storage and version control, milestones management, contract amendments, user performance management.

Researchers and practitioners have identified several challenges in the voyage to an e-procurement platform. For instance, Grilo and Jardim-Goncalves [7] looked into interoperability as a critical challenge. For example, European public tendering procedures require that companies submit certificates and attestations to prove that they comply with selection and exclusion criteria. Electronic business certificates that are interoperable are thus one of the major challenges. Also Electronic signatures interoperability is an important issue. Although technical standards, such as

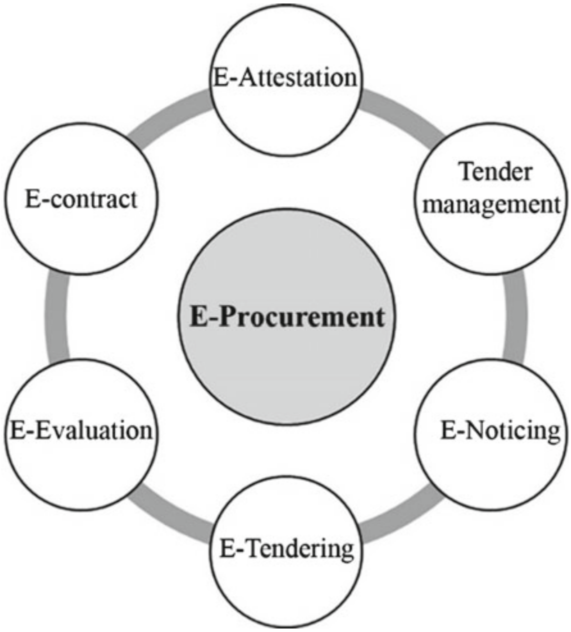


Fig. 70.1 Sections of an e-procurement solution

X.509v3 are available for electronic certificates, and electronic signatures are relatively widespread nowadays, however in practice, many certification authorities do not recognize each other in every case, thus creating identification hurdles.

Logistics play critical role in the success of an e-procurement platform. The study by Bellantuono et al. [5] discussed the different aspects of logistics in auction compared to negotiation from both buyer and seller prospective. According to this study, in the e-procurement platform where buyer initiates the business, the complexity of the logistics should be kept low. In other words, high complexity of logistics will decrease the interest of buyer to select a seller.

Winning factors of an e-procurement platform can classified under two major groups:

(1) the legal framework that must ensure a trustworthy environment in which the business process can be executed under certain and specific security circumstances;
(2) the technical issues in order to afford the proper coordination of processes in a heterogeneous environment where integration and interoperability are key-enablers for the deployment and management of the e-procurement workflow [1].

Apart from the need for standardizing processes and messages for conducting business electronically, the adoption of additional standards is necessary for unifying the manner in which products and services are described in projects in a digital format [3].

In a recent case study in Ghana reported by Godfred et al. [6], an e-procurement platform was implemented in the public sector covering procurement of both goods and services. This study reports the success of e-procurement platform not in a developed and industrial society, but in an emerging economy where the DGP per capital is about 1700 USD, and literacy rate according to the world bank data is low (the female and male ages 15–24 years literacy rate in Ghana was 81 % in 2010, with males at 82 % and females at 80 %).

According to the researches by Ali and Alrayes [1], Alvarez et al. [2], Bellantuono et al. [5], Godfred et al. [6], Khalil and Waly [9], Mose et al. [11], William and Hardy [13], challenges and key advantages of an e-procurement is summarized in Table 70.2.

There is no well-established feasibility study of a comprehensive e-procurement platform in Iran. However, some researchers had shed light some aspects. For instance, Bahreman [4] explored challenges and advantages of employing e-procurement solutions in the cement industry in Iran. His research includes field research in five leading cement industries in Iran resulting in the promising benefits of this approach in this specific industry which has the potential to be generalized to other sectors. In addition, Hanafizadeh and Shafiei Nikabadi [8] developed a framework for selecting an appropriate e-business model in managerial holding companies, especially for the leading automotive company in Iran called Iran Khodro. The automotive industry of Iran is also studied by Mohammadi [10] aiming to identify critical success factors of e-procurement in this country. The presence of automotive industry in case studies of Iranian researchers is rooted in the strong collaboration of this industry (especially the main two car manufacturers) with universities. However, there is lack of scientific work on analysis of the whole Iranian market in order to

Table 70.2 E-procurement challenges and key advantages

E-procurement challenges		E-procurement key advantages	
1.	Implementation costs	1.	Competitive price
2.	Deficient infrastructure	2.	Reduction of procurement cycle time
3.	Lack of interoperability	3.	Reduction of administrative expenses
4.	Lack of business processes and workflows	4.	Transparency
5.	Insufficient e-procurement solutions	5.	Reduction of operating costs
6.	Resistance of middle-managers	6.	Reduction of tied up capital
		7.	Reduction of stock
		8.	Increase accuracy of decisions
		9.	Prevention of corruption attempts
		10.	Expanded network of suppliers
		11.	Access to trade history of buyers and suppliers
		12.	E-Attestation
		13.	Early execution of tasks (i.e. delivery of goods)

identify readiness of Iranian business environment for an e-procurement platform. The next section put forwards valuable information about the Iran's business environment.

70.3 Iran's Business Environment

According to the World Bank (last updated date: Sep 29, 2015), "Iran is the second largest economy in the Middle East and North Africa (MENA) region after Saudi Arabia, with an estimated Gross Domestic Product (GDP) in 2014 of US$ 406.3 billion. It also has the second largest population of the region after Egypt, with an estimated 78.5 million people in 2014" (Table 70.3).

Among the 21 countries located in the MENA region, Iran sits as the 6th country with 72 % of its population are in the age group of 15–64 (Table 70.4; Appendix). The five countries above Iran are mainly dependent to Oil&Gas (O&G) income whereas on September 2015 Iranian government announced its tax income (including value added tax) has taken over the income from O&G sources indicating the large variety of industries and businesses in Iran.

In terms of the area of the country, Iran with an area of 1,648,195 km^2 is more than three times bigger than Spain. However, due to the present of two wide deserts it the center and east side of the country, majority of population is congested in the west and center north (Fig. 70.2). In addition, more than 15 million of about 80 million population of the country live in the Tehran metropolitan area (capital). Hence, there is high population concentration in Iran.

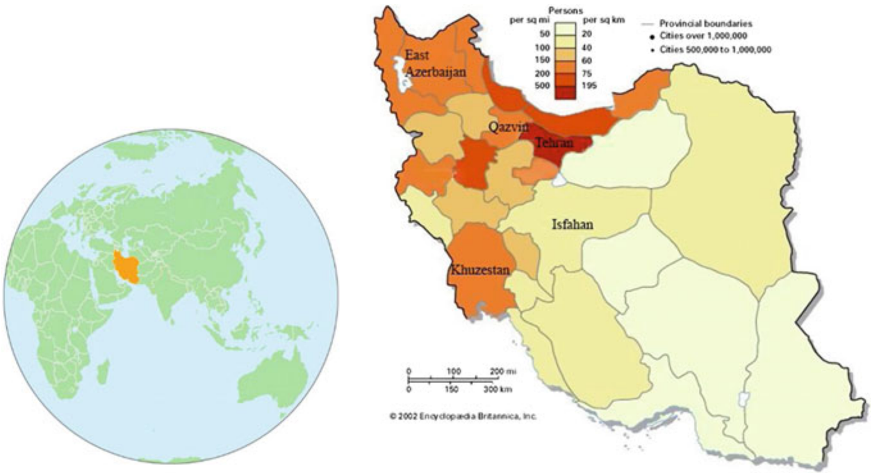


Fig. 70.2 Population distribution in Iran (*dark colors* are more populated)

Table 70.3 Population percentage in the age group 15–64 in the MENA region in 2014

Rank	Country name	Income group	(%)	Region
1	United Arab Emirates	High income	85	Middle East and North Africa
2	Qatar	High income	84	Middle East and North Africa
3	Bahrain	High income	76	Middle East and North Africa
3	Oman	High income	76	Middle East and North Africa
3	Kuwait	High income	76	Middle East and North Africa
6	**Iran**	**Upper middle income**	**72**	**Middle East and North Africa**
7	Tunisia	Upper middle income	69	Middle East and North Africa
8	Saudi Arabia	High income	68	Middle East and North Africa
8	Lebanon	Upper middle income	68	Middle East and North Africa
10	Morocco	Lower middle income	67	Middle East and North Africa
10	Malta	High income	67	Middle East and North Africa
12	Algeria	Upper middle income	66	Middle East and North Africa
12	Libya	Upper middle income	66	Middle East and North Africa
14	Djibouti	Lower middle income	63	Middle East and North Africa
15	Egypt, Arab Rep.	Lower middle income	62	Middle East and North Africa
16	Israel	High income	61	Middle East and North Africa
17	Jordan	Upper middle income	60	Middle East and North Africa
18	Syrian Arab Republic	Lower middle income	59	Middle East and North Africa
19	Yemen, Rep.	Lower middle income	57	Middle East and North Africa
19	West Bank and Gaza	Lower middle income	57	Middle East and North Africa
21	Iraq	Upper middle income	56	Middle East and North Africa

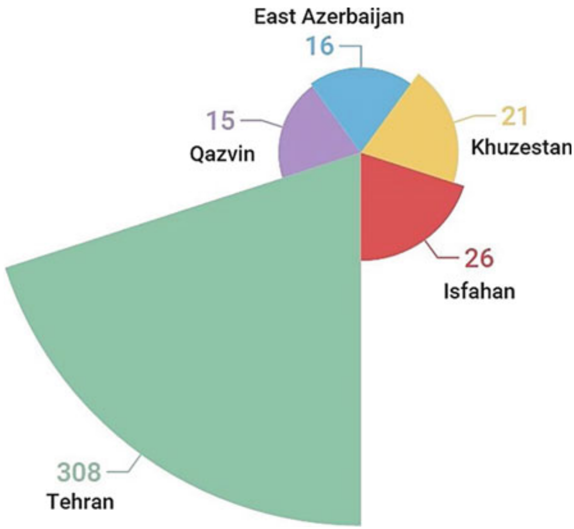


Fig. 70.3 Distribution of 400 top Iranian companies among provinces

The fuel of an e-procurement platform is the active role of big buyers. A successful e-procurement platform should be able to bring in big buyers, thereafter, suppliers of those buyer will require to manage their business through this platform. Big buyers in Iran are operating in a few specific industries namely O&G, banking, automotive, and construction. Recently, many IT based companies have emerged and successfully grow to become one of big buyers. From the geographical perspective, the distribution of big buyers is even less uniform than population distribution. In other words, looking into the top 400 companies of Iran, more than 75 % of them are based in the capital and the rest are distributed in Isfahan, Khuzestan, east Azerbaijan, and Qazvin (Fig. 70.3).

Another key factors which strongly affects the success of an e-procurement platform is the familiarity of people with internet (Fig. 70.4). In a society where people are used to trade on internet, there is less resistance on using e-procurement platform for their B2B relations. Figure 70.5 presents the number of internet used per 100 people from 2000 till 2014 in Iran, MENA, world, upper middle income group (Iran is in this group), and European union. According to this figure that is last update on December 22, 2015 the number of internet used in Iran has exceeded the MENA group countries on 2014. Looking carefully to the slope on which the internet users in Iran grows, it presents higher slope comparing to other groups. To be more specific, since 2012 the number of Iranian internet users grows in a faster rate comparing to other groups. This phenomenon can be justified by the number of smart phones sold in Iran and ease of use of internet packages provided by telecom companies. Thus, regarding this factor, Iran shows success potentials for an e-procurement platform.

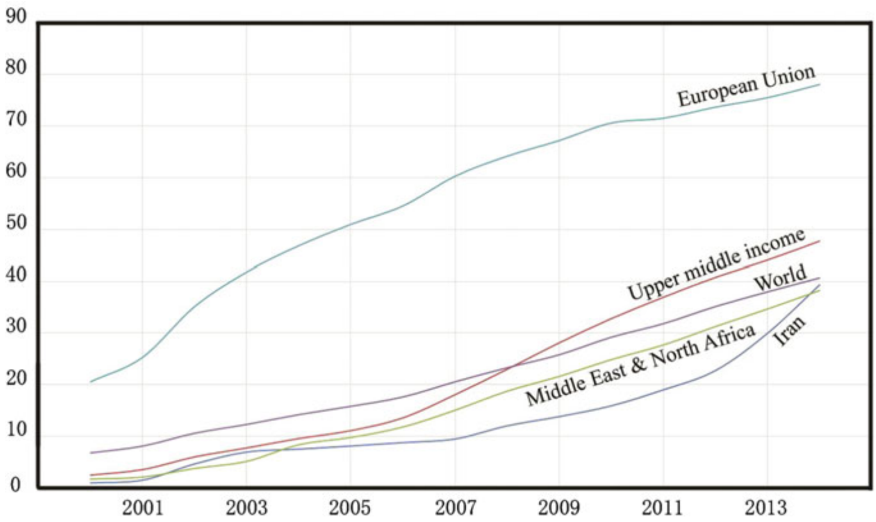


Fig. 70.4 Internet users per 100 people from 2000 till 2014 (*source* World Bank)

70.4 Conclusions

Having a well-established e-procurement platform requires paradigm shift from traditional trading toward e-business. Considering the wide range of key advantages of e-procurement indicates it is a must have platform in all business environment. However, due to its challenges, a number of pre-requisites have to be ready prior to implementation of such platform. This paper looked into key advantages as well as challenges in the implementation of an e-procurement platform.

Due to the fact that implementation feasibility of e-procurement platform has to be studied with respect to the business environment where it is being planned to employed, critical indicators of Iran is investigated. Iran has the highest population percentage in the age group 15–64 in the MENA region with 72 %, indicating the considerable proportion of the population is in the productive age range. In addition, the majority of population is concentrated in a few cities, also top companies are headquartered in a few cities. To be more specific, more than 75 % of top 400 companies are located in Tehran where about 18 % of the whole population is settled.

The other important indicator is the proportion of population who are familiar with internet. The World Bank data proves that internet users in Iran are growing faster than the world and upper middle income group. Thus, every year more people tend to trade over internet which leaves considerable success factor for online businesses.

In summary, study of indicators of the Iranian environments shows although the environment seems to be ready and it is feasible to implement an e-procurement platform, challenges have to be considered and solution to deal with them should be planned ahead.

Acknowledgments UNIDEMI authors would like to thank the Fundação para a Cincia e Tecnologia, Project: UID/EMS/00667/2013.

Appendix: Population Age Group 15–64

A: Percentage of the world population that is in the age group 15–64 (source: World Bank, last updated date: Dec. 22, 2015)

B: Percentage of the total population that is in the age group 15 to 64 in the Upper middle income group (source: World Bank, last updated date: Dec. 22, 2015)

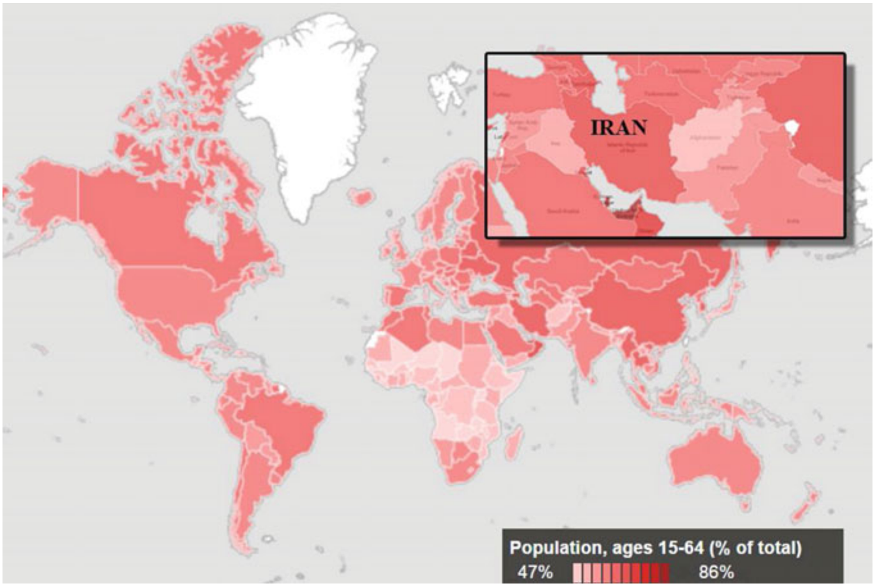


Fig. 70.5 Internet users per 100 people from 2000 till 2014 (*source* World Bank)

Table 70.4 Population percentage in the age group 15–64 in the MENA region in 2014

Country name	2014 (%)	Region	Income group
China	74	East Asia and Pacific	Upper middle income
Iran	**72**	**Middle East and North Africa**	**Upper middle income**
Azerbaijan	72	Europe and Central Asia	Upper middle income
Thailand	72	East Asia and Pacific	Upper middle income
Bosnia and Herzegovina	71	Europe and Central Asia	Upper middle income
Mauritius	71	Sub-Saharan Africa	Upper middle income
Macedonia, FYR	71	Europe and Central Asia	Upper middle income
Belarus	70	Europe and Central Asia	Upper middle income
Cuba	70	Latin America and Caribbean	Upper middle income
Tunisia	69	Middle East and North Africa	Upper middle income
Albania	69	Europe and Central Asia	Upper middle income
Malaysia	69	East Asia and Pacific	Upper middle income
Brazil	69	Latin America and Caribbean	Upper middle income
Costa Rica	69	Latin America and Caribbean	Upper middle income
Colombia	69	Latin America and Caribbean	Upper middle income
Mongolia	68	East Asia and Pacific	Upper middle income
St. Vincent and the Grenadines	68	Latin America and Caribbean	Upper middle income
Lebanon	68	Middle East and North Africa	Upper middle income
Montenegro	6	Europe and Central Asia	Upper middle income
Maldives	68	South Asia	Upper middle income
St. Lucia	68	Latin America and Caribbean	Upper middle income
Romania	67	Europe and Central Asia	Upper middle income
Turkmenistan	67	Europe and Central Asia	Upper middle income
Kazakhstan	67	Europe and Central Asia	Upper middle income
Serbia	67	Europe and Central Asia	Upper middle income
Jamaica	67	Latin America and Caribbean	Upper middle income
Turkey	67	Europe and Central Asia	Upper middle income
Bulgaria	66	Europe and Central Asia	Upper middle income

(continued)

Table 70.4 (continued)

Country name	2014 (%)	Region	Income group
Grenada	66	Latin America and Caribbean	Upper middle income
Suriname	66	Latin America and Caribbean	Upper middle income
Algeria	66	Middle East and North Africa	Upper middle income
Libya	66	Middle East and North Africa	Upper middle income
Mexico	66	Latin America and Caribbean	Upper middle income
Fiji	66	East Asia and Pacific	Upper middle income
South Africa	65	Sub-Saharan Africa	Upper middle income
Peru	65	Latin America and Caribbean	Upper middle income
Panama	65	Latin America and Caribbean	Upper middle income
Botswana	64	Sub-Saharan Africa	Upper middle income
Ecuador	64	Latin America and Caribbean	Upper middle income
Paraguay	64	Latin America and Caribbean	Upper middle income
Dominican Republic	63	Latin America and Caribbean	Upper middle income
Belize	63	Latin America and Caribbean	Upper middle income
Jordan	60	Middle East and North Africa	Upper middle income
Namibia	60	Sub-Saharan Africa	Upper middle income
Gabon	58	Sub-Saharan Africa	Upper middle income
Tonga	57	East Asia and Pacific	Upper middle income
Iraq	56	Middle East and North Africa	Upper middle income
Angola	50	Sub-Saharan Africa	Upper middle income

References

1. Ali H, Alrayes A (2014) An empirical investigation of the effect of e-readiness factors on adoption of e-procurement in kingdom of Bahrain. Int J Bus Manag 9(12):220–229
2. Alvarez JM, Labra JE et al (2012) Towards a pan-european e-procurement platform to aggregate, publish and search public procurement notices powered by linked open data: the moldeas approach. Int J Softw Eng Knowl Eng 22(3):365–383

3. Alvarez-Rodríguez JM, Labra-Gayo JE, Pablos POD (2014) New trends on e-procurement applying semantic technologies. Comput Ind 65(5):797–799
4. Bahreman B (2014) E-procurement in Iran cement industry limitations and benefits. In: 2014 11th international conference on information technology: new generations (ITNG), pp 581–586
5. Bellantuono N, Ettorre D et al (2013) Multi-attribute auction and negotiation for e-procurement of logistics. Group Decis Negot 23(3):421–441
6. Godfred M, Evans N et al (2015) E-procurement as an alternate paradigm to the challenges of procuring goods and services in the public sector-a case study of Ghana Cocoa Board. Eur J Bus Manag 7:68–72
7. Grilo A, Jardim-Goncalves R (2013) Cloud-marketplaces: distributed e-procurement for the AEC sector. Adv Eng Inf 27(2):160–172
8. Hanafizadeh P, Shafiei Nikabadi M (2011) Framework for selecting an appropriate e-business model in managerial holding companies. J Enterp Inf Manag 24:237–267
9. Khalil CA, Waly AF (2015) Challenges and obstacles facing tenderers adopting e-tendering in the public sector of the construction industry in Egypt. Accessed 27 May 2015
10. Mohammadi M (2013) Ranking of critical success factors of e-procurement in Iranian automotive industry. Int Res J Appl Basic Sci 11:3910–3918
11. Mose J, Njihia J, Magutu PO (2013) The critical success factors and challenges in e-procurement adoption among large scale manufacturing firms in Nairobi, Kenya. Eur Sci J 9:375–401
12. Vaidya K, Campbell J (2014) Multidisciplinary approach to defining public e-procurement and evaluating its impact on procurement efficiency. Inf Syst Front 1–16
13. William S, Hardy C (2007) E-procurement: current issues and future challenges. In: European conference on information systems, pp 131–142
14. Yu S, Mishra AN et al (2015) E-procurement infusion and operational process impacts in mro procurement: Complementary or substitutive effects? Prod Oper Manag 24(7):1054C1070

Chapter 71
Female Audit Committee Member's Characteristics and High Quality External Audit Demand

Rui Xiang and Meng Qin

Abstract This paper empirically tests the effect of female audit committee member's characteristics on high quality external audit demand. We use a sample of China's A share listed companies during the period 2004 to 2007. The results show that the education level and academic background of women serving as audit committee members have significant positive influence on high quality external audit demand while multiple identities are negatively significantly associated with high quality external audit demand. Meanwhile the female director's accounting expertise, age and political/audit firm/business backgrounds have no significant impact on high quality external audit demand. Further analysis shows that in both state-owned and non-state-owned firms, female director's education level is positively significantly related to high quality external audit demand while the significant association between female director's multiple identities/academic background and high quality external audit demand only exists in non-state firms. Female director's other characteristics do not significantly affect high quality external audit demand in either state-owned firms or non-state companies. This paper provides some empirical evidence for further improving the audit committee system in China.

Keywords Audit committee · Female directors · Background characteristics · Audit demand

71.1 Introduction

In the beginning of 2002, the Securities Regulatory Commission and the National Economics and Trade Commission of the People's Republic of China jointly issued The Code of Corporate Governance for Chinese Listed Companies. It requires that the audit committee should be formed by the board of directors in listed companies

R. Xiang (✉) · M. Qin
Business School, Sichuan University, Chengdu 610064,
People's Republic of China
e-mail: xiangrui@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_71

and states clearly that one of the major responsibilities of the audit committee is proposing the employment and switch of external audit institutions. This marks that audit committees have become an important part in corporate governance. And it indicates that audit committees will play the significant role of supervising in listed firms.

The existing Chinese literature mainly focuses on the factors that affect the formation of audit committees [29, 31, 33]; the characteristics of audit committees [22, 27, 28]; and the wealth effect of audit committees [15]. There is no Chinese literature dealing with the effects of women who serve as audit members and their characteristics on the performance of corporate governance. In English literature, some literature starts to focus on the impact of gender diversity of audit committees on corporate governance [14, 15, 24, 25]. However, this literature rarely deals with female director's characteristics, such as accounting expertise, education level, age, multiple identities and professional background. These characteristics may affect female director's effectiveness of executing duties and thus further impact the governance of audit committees. In summary, it can be seen that on the one hand, Chinese literature hardly pays attention to gender diversity when studying audit committees. On the other hand, although some English literature starts to focus on gender diversity, the issue of female directors' personal characteristics is still ignored.

This paper systematically tests the effect of female director's characteristics of the audit committee on high quality external audit demand. We expect to provide some empirical evidence for female directors to function well in corporate governance of listed firms.

This paper examines the impact of female audit committee member's different characteristics on the governance of audit committees from the perspective of high quality external audit demand for the first time in history, using a sample of China's A share listed companies during the period 2004 to 2007. We show that female director's education level and academic background are positively significantly related to high quality external audit demand, multiple identities have significant negative effect on high quality external audit demand. Accounting expertise, age, government/audit firm/corporation backgrounds are insignificant for high quality external audit demand. We also find that female audit committee member's education level is significantly relevant to high quality external audit demand in both state-owned and non-state firms while multiple identities and academic background are only significantly related to high quality external audit demand in non-state firms.

This paper contributes to the literature in three ways. First, we test the effect of female audit committee member's characteristics on high quality external audit demand for the first time in history. Second, we show the impact of female director's different characteristics on the governance of audit committees in the special institutional context of China. Thus we provide some empirical evidence for further improving the audit committee system in China. Third, we examine the effect of female director's characteristics of the audit committee on high quality external audit demand from the perspective of ownership type, which may provide some help in deepening the reform of China's ownership structure.

This study extends the existing literature on the gender diversity of audit committees by considering the characteristics of a new transitional economy. And it examines the female director's characteristics which may affect the functioning of audit committees. Future research can explore other socio-economic groups that might have impact on the effectiveness of certain organizations in China or other emerging markets.

The rest of the paper proceeds as follows: Sect. 71.2 presents theoretical analysis and develops hypotheses. Section 71.3 is the research design, including sample selection, data source, empirical models and variable definitions. Empirical results, discussion and comments including further analysis and checks on the robustness of our findings are presented in Sects. 71.4 and 71.5. The last section provides concluding remarks.

71.2 Theoretical Analysis and Hypotheses Development

Independent and active audit committees tend to persuade management to choose auditors of higher quality or with better reputation [1]. This paper uses relevant women theories [2, 7, 20] and follows the logic of "female director's characteristics-management decision- external audit demand" to systematically examine the effect of female audit committee member's characteristics on high quality external audit demand.

71.2.1 Accounting Expertise and External Audit Demand

Singh et al. [21] documented that in U.K., 35 % of female directors have certificates of accounting and 25 % of female directors have once worked as CFOs. Peni and Vhmaa [19] found that female CFOs are associated with income-decreasing discretionary accruals, thereby implying that female CFOs are following more conservative earnings management strategies. Women with accounting expertise may regard earnings management as highly risky from the perspective of laws and careers. Beckmann and Menkhoff [3] documented that female financial experts remain more risk averse and less over-confident. Based on the analysis above, we argue that female audit committee members with accounting expertise may have the ability to identify the risk of accounting information and demand better audits. The hypothesis is stated as follows:

Hypothesis 1 (H1): when more women with accounting expertise sit on the audit committee, the company has higher quality external audit demand.

71.2.2 Education Level and External Audit Demand

Generally speaking, one's comprehensive quality is closely associated with his/her education level. Barker [2] found that with higher education level, people have better cognitive ability. The knowledge and information accumulation of men and women in a certain field are different due to their different interests and hobbies. The education level of women reflects their cognitive and professional abilities. Hillman et al. [13] showed that female directors can increase the board's education levels. Smith et al. [22] documented that when women with high education levels serve as directors, they have significant positive effect on the firm's financial performance. Based on the analysis above, we argue that when female audit committee members have high education levels, the audit committee functions better in supervising, leading the management to choose high quality external audit demand. We state our hypothesis as follows:

Hypothesis 2 (H2): With higher education level of female audit committee members, the company has higher quality external audit demand.

71.2.3 Age and External Audit Demand

The age shows one's social experiences. People of different ages have different perceptions about society because the have experienced different periods of history and society. This may affect their values and beliefs. The management's ages represent their experiences and attitudes towards risks, influencing their choices of behavior. Hambrick and Mason [11] and Barker and Mueller [2] found that older management tend to make decisions that are less risky. Hersch [12] argued that women have longer expected lifespan and thus risky behaviors may cause more losses, making women more cagy about decisions. Thus we argue that older women on the audit committee may ask for higher quality external audit demand due to the consideration of avoiding risks. Our hypothesis is:

Hypothesis 3 (H3): Older female audit committee members lead to higher quality external audit demand in the company.

71.2.4 Multiple Identities and External Audit Demand

According to the reputation effect, directors with good social reputations tend to perform their duties better in order to lower the cost of reputation damage [18, 26]. However, some scholars argue that independent directors with too many identities will not supervise effectively [4, 8]. Xiang [30] found that financial independent directors who have multiple identities decrease the accounting conservatism. Based on the analysis above, we argue that on the one hand, when female audit committee members have multiple identities, they have better social reputation and they may demand higher quality external audit. On the other hand, multiple identities may make them spend less time performing their supervising duties, thus decreasing the company's demand for higher quality external audit. We state the two compelling hypotheses as follows:

Hypothesis 4a (H4a): More female directors with multiple identities are associated with higher quality external audit demand of the company.

Hypothesis 4b (H4b): More female directors with multiple identities are associated with lower quality external audit demand of the company.

71.2.5 Professional Background and External Audit Demand

Kaplan and Reishus [17] considered the academic background as a mark for outside connection. Singh et al. [21] found that 12.5 % of female directors have academic backgrounds in U.K. Burk and Mattis [18] argued that in U.S., the so-called "high-level" women are preferred to be the directors on the board, signaling the company's great actual strength. Hillman et al. [13] documented that female directors can bring knowledge and professional expertise to the board. Based on the analysis above, we argue that because female directors with academic background are well educated and have good social reputations, they can help the audit committee supervise better and thus the company may have higher quality external audit demand. Thus our hypothesis is:

Hypothesis 5a (H5a): More female audit committee members from the academic institutions are relevant with higher quality external audit demand of the company.

Fishman [9] documented that connections with key political figures may increase corporate value. Wei et al. [10] found that independent directors with government background can elevate financial performance. Pan [19] showed that non-state-owned firms that have entrepreneurs with political background tend to hire large audit firms. Thus we argue that because female audit committee members with political background need to protect their reputations and perform the administrative supervising duties, they may demand higher quality external audit. Thus we state our hypothesis as follows:

Hypothesis 5b (H5b): More female audit committee members from government sectors are associated with higher quality external audit demand of the company.

DeAngelo [6] argued that CPAs have the ability to detect problems in the accounting system. Song et al. [23] found that independent directors with CPA title can significantly increase the accuracy of management predictions. Xiang [30] showed that more financial directors from audit firms can increase accounting conservatism in companies. Thus we argue that because female audit committee members from audit firms have better professional ability and more practical experiences which helps the audit committee to function better in supervising, the company demands higher quality external audit. Thus our hypothesis is:

Hypothesis 5c (H5c): More female audit committee members from audit firms are relevant with higher quality external audit demand of the company.

In China, audit committees tend to employ directors who are from business circles. These people have many practical experiences in management/operational decisions and focus more on the company's development, increasing corporate value. Thus we argue that because female audit committee members from business circles have many experiences in management, they help audit committees to make better decisions and the company may have higher quality external audit demand. Our hypothesis is:

Hypothesis 5d (H5d): More female audit committee members from business circles are associated with higher quality external audit demand of the company.

71.3 Research Design

71.3.1 Sample Selection and Data Source

We use a sample of China's A share listed companies during the period 2004 to 2007. And based on this, we delete companies that do not disclose information on female audit committee members and further delete financial firms and those with insufficient data of variables. We collected the data of female audit committee members by hand and other data were obtained from the CSMAR (China Security Market Accounting Research) database.

71.3.2 Empirical Models and Variable Definitions

This paper constructs the following models to examine the effect of female audit committee member's characteristics on high quality external audit demand: Model (71.1) is used for testing H1–H2:

$$\text{BIG4} = \beta_0 + \beta_1\text{ACCOUNT} + \beta_2\text{EDU} + \beta_3\text{Controls} + \varepsilon. \qquad (71.1)$$

Model (71.2) is for H3–H4:

$$\text{BIG4} = \beta_0 + \beta_1\text{AGE} + \beta_2\text{MULT} + \beta_3\text{Controls} + \varepsilon. \qquad (71.2)$$

Table 71.1 Degree type and its score

Degree type	Score
Ph.d	5
Master's degree	4
Bachelor's degree	3
Technical junior college degree	2
Vocational secondary school degree or lower	1

Model (71.3) is for H5a–H5c:

$$BIG4 = \beta_0 + \beta_1 \text{ACAD} + \beta_2 GOV + \beta_3 \text{AFIR} + \beta_4 \text{CORP} + \beta_5 \text{Controls} + \varepsilon. \tag{71.3}$$

where BIG4 is the dependent variable set to 1 if the audit firm is one of the four largest international audit firms, 0 otherwise. The explanatory variables' definitions are as follows: ACCOUNT denotes the percentage of female members with accounting expertise to total number of female directors on the committee. EDU represents the average score of female members' education levels. It is shown in the following Table 71.1:

AGE measures the average age of female directors on the committee. MULT is the ratio of female members who serve as senior management in other firms to total number of female directors on the committee. ACAD denotes the percentage of female members who are from academic institutions to total number of female directors on the committee. GOV is the percentage of female members from government sectors to total number of female directors on the committee. AFIR measures the ratio of female members from audit firms to total number of female directors on the committee. COPR is the percentage of female members from business circles to total number of female directors on the committee.

Controls are control variables: ANUM is a measure of the total number of members on the audit committee. WMAN is the male director ratio specified as the percentage of male members to total number of directors on the committee. WIND denotes the ratio of independent female members to total number of female directors on the committee. DUAL is a dummy variable set to 1 if the two positions of board chair and CEO are held by the same individual, 0 otherwise. OUTDIR denotes the independence degree of the board which is the ratio of independent directors to total number of directors on the board. CFO denotes fiscal year end (hereafter FYE) net cash flow from operations to total assets. LEV is the asset-liability ratio specified as FYE total debt to total assets. SIZE is measured as the natural log of FYE assets. LOSS is a dummy variable set to 1 if the firm has incurred a loss, 0 otherwise. STATE is a dummy variable set to 1 if the firm is state-owned, 0 otherwise.

Table 71.2 Descriptive statistics

Variables	Min	Max	Mean	Median	Std.
BIG4	0	1	0.05	0	0.209
ACCOUNT	0	1	0.56	0.5	0.476
EDU	1	5	2.65	2	0.907
AGE	27	71	46.36	45	7.676
MULT	0	1	0.37	0	0.467
ACAD	0	1	0.28	0	0.437
GOV	0	1	0.09	0	0.275
AFIR	0	1	0.18	0	0.38
CORP	0	1	0.47	0.5	0.5

71.4 Empirical Results and Discussion

71.4.1 Descriptive Statistics

Table 71.2 presents the descriptive statistics. The mean value of BIG4 is 0.050, suggesting that only 5 % of listed firms in China have high quality external audit demand. The mean value of ACCOUNT is 0.560, indicating that the majority of female directors have accounting expertise. The mean value of EDU is 2.650, suggesting that the average degree female directors hold is close to a Bachelor's degree. The max, min and mean value of age are 71, 27 and 46.36 respectively, suggesting that the distribution of age varies greatly. The mean value of MULT is 0.370, indicating that 37 % of female directors on the committee simultaneously serve as senior management in other firms. The mean value of ACAD is 0.280, suggesting that 28 % of female directors are from academic institutions. The mean value of GOV is 0.090, suggesting that 9 % of female directors have political backgrounds. The mean value of AFIR is 0.180, suggesting that 18 % of female audit committee members are from audit firms. The mean value of CORP is 0.470, suggesting that 47 % of women are from business circles.

71.4.2 Regression Results and Analysis

(1) Accounting Expertise and Education Level

Table 71.3 reports the regression results for Model (71.1). Female directors with accounting expertise have positive impact on high quality external audit demand but the coefficient is not significant, suggesting that their accounting expertise does not affect high quality external audit demand significantly. Thus our hypothesis H1 is not supported. However, the variable EDU is positively significantly (at the 1 % level)

Table 71.3 The effect of accounting expertise and education level on high quality external audit demand

Explanatory variables	Dependent variable: BIG4 (high quality external audit demand)		
	Coeffecient	Wald-value	p-value
Constant	−38.679***	43.782	0
ACCOUNT	0.019	0.002	0.965
EDU	0.650***	10.388	0.001
ANUM	0.258*	3.259	0.071
WMAN	1.007	0.402	0.526
WIND	−0.381	0.664	0.415
DUAL	−2.052*	3.455	0.063
OUTDIR	2.873	0.321	0.571
SIZE	1.579***	39.131	0
LOSS	1.072	2.226	0.136
LEV	−4.977***	12.742	0
CFO	−0.088	0.861	0.353
STATE	−1.225***	6.916	0.009
N	719		
−2Log likelihood	187.796		
Cox & Snell R^2	0.105		

Note: *, ** and *** denote significance at the 0.1, 0.05 and 0.01 levels, respectively (two-tailed)

associated with high quality external audit demand, suggesting that female directors with high education levels help the committee to function better in supervising and thus the demand for high quality external audit increases. Thus our hypothesis H2 is supported.

(2) Age and Multiple Identities

Table 71.4 presents the regression results of Model (71.2). The age of female directors is not positively significantly relevant to high quality external audit demand. Thus our hypothesis H3 is not supported. MULT is negatively significantly (at the 10 % level) associated with high quality external audit demand, indicating that multiple identities may make female directors spend less time performing their supervising duties, thus decreasing the company's demand for high quality external audit. Thus our hypothesis H4b is supported.

(3) Professional Background

Table 71.5 reports regression results of Model (71.3). ACAD is positively significantly (at the 10 % level) associated with high quality external audit demand. This is probably because female directors with academic background are well educated and have good social reputation, the committee functions better. Thus the demand for high quality external audit increases. Thus, our hypothesis H5a is supported. The other three variables for professional background (GOV, AFIR and COPR) are positively related to high quality external audit demand but not significant. Thus none of our hypotheses H5b, H5c and H5d is supported.

Table 71.4 The effect of age and multiple identities on high quality external audit demand

Explanatory variables	Dependent variable: BIG4 (high quality external audit demand)		
	Coefficient	Wald-value	p-value
Constant	−35.073***	39.88	0
AGE	−0.12	0.197	0.658
MULT	−0.853*	3.13	0.077
ANUM	0.273*	3.78	0.052
WMAN	−1.51	0.876	0.349
WIND	−0.404	0.734	0.392
DUAL	−2.154*	3.632	0.057
OUTDIR	3.319	0.321	0.571
SIZE	1.513***	38.564	0
LOSS	0.949	1.748	0.186
LEV	−5.062***	13.823	0
CFO	−0.078	0.668	0.414
STATE	−1.119**	5.948	0.015
N	719		
−2Log likelihood	194.382		
Cox & Snell R^2	0.097		

Note: *, ** and *** denote significance at the 0.1, 0.05 and 0.01 levels, respectively (two-tailed)

71.4.3 Further Analysis

Table 71.6 presents regression results of Models (71.1)–(71.3) after we divide the companies into state-owned and non-state-owned firms. It shows that in both state-owned and non-state-owned firms, female director's education level is positively significantly (at the 10 % level) related to high quality external audit demand, supporting our hypothesis H2. The significant association between female director's multiple identities/academic background and high quality external audit demand only exists in non-state firms. Moreover, in both state-owned and non-state-owned firms, none of the other explanatory variables (ACCOUNT, AGE, GOV, AFIR and CORP) is significantly relevant to high quality external audit demand.

71.5 Robustness Checks

We perform the following robustness checks in order to check the reliability of our results:

(1) We redefine the dependent variable by using the 10 largest domestic audit firms (BIG10) rather than the 4 largest international audit firms (BIG4). The new

Table 71.5 The effect of professional background on high quality external audit demand

Explanatory variables	Dependent variable: BIG4 (high quality external audit demand		
	Coefficient	Wald-value	p-value
Constant	−35.150***	40.517	0
ACAD	1.293*	3.509	0.061
GOV	1.127	1.751	0.186
AFIR	0.79	1.138	0.286
CORP	0.295	0.199	0.656
ANUM	0.331**	4.971	0.026
WMAN	0.443	0.073	0.787
WIND	−0.438	0.799	0.371
DUAL	−1.962*	3.254	0.071
OUTDIR	3.547	0.483	0.487
SIZE	1.460***	36.377	0
LOSS	0.892	1.542	0.214
LEV	−5.061***	13.256	0
CFO	−0.062	0.473	0.492
STATE	−1.085**	5.549	0.018
N	719		
−2Log likelihood	192.61		
Cox & Snell R^2	0.099		

Note: *, ** and *** denote significance at the 0.1, 0.05 and 0.01 levels, respectively (two-tailed)

results (not tabulated) are consistent with Table 71.3 through 5, which support the results discussed earlier.

(2) We control for time and industry effects by adding two dummy variables: YEAR and IND. The new results (not tabulated) are consistent with Table 71.3 through 5, which support the results discussed earlier.

71.6 Conclusion

This paper tests the effect of female audit committee member's characteristics on high quality external audit demand using a sample of China's A share listed companies during the period 2004 to 2007. The results show that the education level and academic background of women serving as audit committee members have significant positive influence on high quality external audit demand while multiple identities are negatively significantly associated with high quality external audit demand. Meanwhile the female director's accounting expertise, age and political/audit firm/business backgrounds have no significant impact on high quality external audit demand. Further analysis shows that in both state-owned and non-state-owned firms, female

Table 71.6 Female director's characteristics and high quality external demand: regression analysis of the subsamples separated by ownership structure

Explanatory variables	Dependent variable: BIG4 (high quality external audit demand)					
	State-owned firms			Non-state firms		
	Model (71.1)	Model (71.2)	Model (71.3)	Model (71.1)	Model (71.2)	Model (71.3)
Constant	−37.425***	−32.480***	−36.278***	−53.691***	−57.260***	−50.320***
	0	0	0	0	0	0
ACCOUNT	0.42	–	–	−0.403	–	–
	−0.46	–	–	−0.598	–	–
EDU	0.488*	–	–	0.787**		–
	−0.056	–	–	−0.028	–	–
AGE	–	−0.034	–	–	0.003	–
	–	−0.351	–	–	−0.947	–
MULT	–	−0.073	–	–	−1.899*	–
	–	−0.901	–	–	−0.068	
ACAD	–	–	1.31	–	–	1.304*
	–	–	−0.171	–	–	−0.054
GOV	–	–	1.26	–	–	1.275
	–	–	−0.278	–	–	−0.356
AFIR	–	–	0.163	–	–	1.869
	–	–	−0.876	–	–	−0.155
CORP	–	–	0.395	–	–	0.491
	–	–	−0.666	–	–	−0.591
Controls	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
N	438	438	438	281	281	281
−2Log likelihood	118.545	121.703	119.277	59.405	60.217	61.883
Cox & Snell R^2	0.108	0.101	0.106	0.132	0.129	0.124

Note: Controls do not include the variable STATE. *, ** and *** denote significance at the 0.1, 0.05 and 0.01 levels, respectively (two-tailed)

director's education level is positively significantly related to high quality external audit demand while the significant association between female director's multiple identities/academic background and high quality external audit demand only exists in non-state firms. Female director's other characteristics do not significantly affect high quality external audit demand in either state-owned firms or non-state companies.

References

1. Abbott LJ, Parker S (2000) Auditor selection and audit committee characteristics. Auditing J Pract Theor 19(2):47–66
2. Barker VL III, Mueller GC (2002) Ceo characteristics and firm R&D spending. Manag Sci 48(6):782–801
3. Beckmann D, Menkhoff L (2008) Will women be women? analyzing the gender difference among financial experts. Kyklos 61(3):364–384
4. Core JE, Holthausen RW, Larcker DF (1999) Corporate governance, chief executive officer compensation, and firm performance. J Financ Econ 51(3):371–406
5. Dallas LL (2002) New managerialism and diversity on corporate boards of directors. Tulane Law Rev 76:1363–1405
6. DeAngelo LE (1981) Auditor independence, 'low balling', and disclosure regulation. J Account Econ 3(2):113–127
7. Eagly AH, Carli LL (2003) The female leadership advantage: an evaluation of the evidence. Leadersh Quart 14(6):807–834
8. Ferris SP, Jagannathan M, Pritchard AC (2003) Too busy to mind the business? monitoring by directors with multiple board appointments. J Financ 58(3):1087–1111
9. Fisman R (2001) Estimating the value of political connections. Am Econ Rev 91(4):1095–1102
10. Gang W, Zezhong X et al (2007) Background of independent directors and corporate performance. Econ Res J 3:008
11. Hambrick DC, Mason PA (1984) Upper echelons: the organization as a reflection of its top managers. Acad Manag Rev 9(2):193–206
12. Hersch J (1996) Smoking, seat belts, and other risky consumer decisions: differences by gender and race. Manag Decis Econ 17:471–481
13. Hillman AJ, Cannella AA, Harris IC (2002) Women and racial minorities in the boardroom: how do directors differ? J Manag 28(6):747–763
14. Huang HW, Yan YC, Fornaro JM, Elshahat A (2011) Market reactions to audit committee director's gender: evidence from us-traded foreign firms. Int J Bank Financ 8(1):4
15. Ittonen K, Miettinen J, Vähämaa S (2010) Does female representation on audit committees affect audit fees? Q J Financ Account 49:113–139
16. Jungwirth C, Burke RJ, Mattis MC (2001) Women on corporate boards of directors. International Challenges and Opportunities, pp 43–45
17. Kaplan SN, Reishus D (1990) Outside directorships and corporate performance. J Financ Econ 27(2):389–410
18. Miwa Y, Ramseyer JM (2000) Corporate governance in transitional economies: lessons from the prewar Japanese cotton textile industry. J Legal Stud 29(1):171–203
19. Pan KQ (2010) Actual controller's political identity, self-discipline governance and audit demand: evidencerom non-state listed firms before IPO. Auditing Res 4:57–65
20. Schubert R (2006) Analyzing and managing risks-on the importance of gender differences in risk attitudes. Manag Financ 32(9):706–715
21. Singh V, Terjesen S, Vinnicombe S (2008) Newly appointed directors in the boardroom: How do women and men differ? Eur Manag J 26(1):48–58
22. Smith N, Smith V, Verner M (2006) Do women in top management affect firm performance? a panel study of 2,500 danish firms. Int J Prod Perform Manag 55(7):569–593
23. Song Y, Ji X, Lee CWJ (2013) Ownership balance, supervisory efficiency of independent directors and the quality of management earnings forecasts. China J Account Res 6(2):113–132
24. Stewart J, Munro L (2007) The impact of audit committee existence and audit committee meeting frequency on the external audit: Perceptions of australian auditors. Int J Auditing 11(1):51–69
25. Thiruvadi S (2012) Gender differences and audit committee diligence. Gend Manag Int J 27(6):366–379

26. Vafeas N (1999) Board meeting frequency and firm performance. J Financ Econ 53(1):113–142
27. Wang XY, Zhang SC, Gao Y (2008) An empirical study on audit committee characteristic and auditor change. Auditing Res 4:87–96 (in Chinese)
28. Wang XY, Guan KL (2006) The empirical study on audit committee characteristics and information disclosure quality. Auditing Res 6:42–49
29. Xia WX (2005) Major shareholders' characteristics and the foundation of audit committee. Auditing Res 6:45–50
30. Xiang R (2013) Financial independent director's characteristics and accounting conservatism. In: The 19th annual conference of China financial society, vol 2013, pp 109–119 (in Chinese)
31. Xiang R, Gan S, Wang L (2010) The wealth effect of announcement of audit committee formation-empirical evidence from Chinese listed companies. J Sichuan Univ Humanit Soc Sci 3:109–119 (in Chinese)
32. Xiang R, Li QQ (2010) The environment of corporate governance and voluntary formation of the audit committee: evidence from China's listed companies. J Shanxi Financ Econ Univ 12:111–117 (in Chinese)
33. Yang ZL, Xu ZD (2004) The motivation of audit committee's formation in China. Auditing Res 1:19–24 (in Chinese)
34. Yu S, Lord R et al (2010) Female executives and earnings management. Manag Financ 36(7):629–645

Chapter 72
Research for the Medical-Guidance Cognitive Behaviors of Patients in General Hospitals

Yueyu Li

Abstract Although the three-A General Hospitals are generally provided with various medical guidance information and consultation desks for patients, in the complex spatial environment, improper medical information setting, and anxiety etc., thus patients and relatives still can't solve their own spatial position problems in General Hospitals and get lost in their medical guidance, and so as to resort to medical staff. This serious problem of time-consuming medical guidance lost reduces the overall efficiency of the service for both doctors and patients. This paper first analyzes the medical guidance needs of the patients and relatives, then defines the cognitive map and medical nodes of spatial structure in General Hospitals, and uses the cognitive psychology and Shannon entropy method etc., analyses medical guidance modes of patients and relatives in General Hospitals, as well as the cognitive processes and uncertainty of information carriers (Sign or Kanban) of medical guidance chain in a rational state, and investigates how to solve the scientific problems about their spatial location in General Hospitals. On this basis, this paper infers to the setting principle of medical guidance information system in General Hospitals. This paper has the important theoretical value for the theoretical research of medical-guidance cognitive behaviors about patients and relatives in General Hospitals.

Keywords General hospital · Patients · Medical guidance · Cognitive behaviors

72.1 Introduction and Objectives

At present, in the three-A General Hospitals (hereinafter referred to as General Hospital) of China, the actual process for patients searching medical service is: at the day for treatment, based on the various medical information clues they get from

Y. Li (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: liyueyu@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_72

the surrounding of General Hospitals (including medical staff and information desk), patients initiatively search the entire process of medical treatment by themselves.

The General Hospitals provide a variety of marked medical guidance information in their buildings (inside and outside) to make the patient easy to identify and treatment, as well as relatives to visit for convenient. But for the first time, both patients and visitors will find still often to get lost in the complex space environment of General Hospitals, patients and relatives themselves can not use medical guidance information clues they get to solve the scientific problem of the complex space location in General Hospitals, so they have to the medical staff help and the cognitive behavior uncertainty of medical guidance appears, which severely reduces the comprehensive service efficiency between doctors and patients.

According to the domestic and foreign survey, each treatment time for one patient is about 1.5–4 h and there are 7 to 25 steps from registration to leaving [3]. While patients have to suffer physical discomfort, they find and shuttle in various medical departments in the complex and unfamiliar environment of General Hospitals, and do all kinds of the cumbersome procedures, examinations and treatments. Thus their physiological and psychological burden is heavy, it is easy for them to get anxious, which makes the cognitive behavior uncertainty of medical guidance more serious.

Foreign scholars have conducted some research on the issue of medical guidance. Barbara [3] considered that the hospital's guidance system must be designed to understand the needs of patients and visitors. Ulrich et al. [7] studied the guidance signs and information clues of medical. Ann [2] believed the roles of plan configuration and manifest cues in wayfinding is very important. Mi et al. [4] demonstrated that current wayfinding aids in hospital are insufficient to support a person's natural navigational behaviors in the environment. Cheng and Pérez–Kriz [1] found maps can indeed assist visitors in finding their way through complex buildings, but that there are limitations to their ability to overcome architectural barriers. Rooke [6] believed design the signs of an effective guidance system in a complex hospital environment must ensure that the correct information is transmitted to the right person at the right time with the right form. But foreign scholars generally lack the theoretical study of medical guidance.

To solve the medical guidance problem for patients and relatives searching treatment is the searching process in problem space which is obtained by the operator of guidance information clues.

Firstly, the physical space of the start node where are the guidance information clues of the target node is searched. Secondly, it is necessary to search how much of the guidance information clues of the target node, to remove and validate interference information, and then decide how to find a medical guidance path to the target node.

This paper focuses on the theoretical issues for medical-guidance cognitive behavior of patients and relatives-how to solve their spatial problem in General Hospitals. Because of their small size, relatively simple structure of the ordinary hospitals (the secondary hospitals following), and in foreign public hospitals patients are comparatively smaller and medical guidance problem is not prominent, so this paper is not care about them.

72.2 Materials and Methods

72.2.1 Guidance Needs of Patients in General Hospitals

The needs of medical guidance information for patients and their relatives in General Hospitals include medical treatment process information and the corresponding position information of medical resources. General medical treatment process information include registration, waiting in clinics or in hall, treatment, being in hospital, payment, taking medicine, and being out of the hospital etc. Medical resource location information include the spatial position information of various departments corresponding to medical treatment process in General Hospitals.

Now in most cases patients and their relatives can probably obtain the medical guidance information clues through searching the space environment (including the medical staff and the consultation desk) in General Hospitals, and then according to the medical guidance information clues, in a hurry they make decision find the medical guidance paths and the corresponding departments quickly and accurately in the complex spatial structure of General Hospitals. But the uncertainty of medical guidance process for the newly diagnosed patients or relatives may be high, low efficiency.

Let C for a collection of medical guidance information clues obtaining by patients and relatives.

72.2.2 Cognitive Map of Spatial Structure and Classification of Medical Nodes in General Hospitals

Before discussing the problem of the medical-guidance cognitive behavior, with Graph theory, this paper abstracts the various departments and regions of the spatial structure in General Hospitals regarded as each medical nodes P_n, and finding their doors, windows, entrances and exit can find these departments and regions, and to abstract the paths (such as corridors) of the spatial structure in General Hospitals as the corresponding edge L_n, that is medical guidance paths. The collection of all medical nodes and the guidance paths constitute the cognitive map of the complex spatial structure of General Hospitals, namely $CG = (P_n, L_n)$. The cognitive map includes Point Set P_n and the Edge Set L_n (n is positive integer), and then medical nodes is classified the following based on the cognitive map CG (Table 72.1).

Table 72.1 Medical node classification of cognitive map in General Hospitals

Number	Type of medical nodes	Illustration
1	Starting node $P(s)$	The starting place of medical guidance
2	Target node $P(t)$	The destination of medical guidance
3	Middle node $P(m)$	The intermediate place of medical guidance
4	Visible node $P(v)$	The node of medical guidance within the normal line of sight
5	Non-visible node $P(nv)$	The node of medical guidance outside the normal line of sight
6	Interference node $P(i)$	The spatial information will interfere medical-guidance cognitive decision making in the node, such as cross-road
7	Judgment node $P(j)$	Patients should decide to choose which path based on certain guidance

72.2.3 *Cognitive Behavior Mode of Medical Guidance for Patients of General Hospitals in the Rational State*

For patients and relatives, the basic cognitive behavior process of initial medical guidance in the spatial structure cognitive map CG of General Hospitals is: at the start node $P(s)$, they should get the initial medical guidance information clue C about the target node $P(t)$ and maintain C, then guide by themselves in the CG of General Hospitals until reaching target node $P(t)$. The paper uses information theory method to analyze the following situations.

(1) In Ideal Situation

Patients and relatives get the initial guidance information clue C at the starting point $P(s)$, and then guide by themselves. If finding the information clue T of target node $P(t)$ as same as C, they can reach target node $P(t)$ successfully, thus the medical guidance process complete. It can be showed in mathematic logic expression:

$$\text{At } P(s) : \exists C,\ \text{ if } P(t) : \exists T,\ \text{ and } C = T,\ \text{ then } \rightarrow P(t). \tag{72.1}$$

Conversely, patients and relatives do not get the initial guidance information clue C at the starting point $P(s)$, or they do not find the information clue T of target node $P(t)$ as same as C during the guidance process by themselves, then the medical guidance process must be continued or may be lost. That is:

$$\text{At } P(s) : \overline{\exists} C,\ \text{ or } C \neq T,\ \text{ then } \rightarrow \Phi. \tag{72.2}$$

(2) In Non-ideal Situation

Because of the various interference information Z actually in the complex spatial structure of General Hospitals, there are three basic medical guidance situations for patients and relatives:

- They get incomplete initial guidance information clue C'(content interference) at the starting point $P(s)$, and they fail to find the information clue T of target node $P(t)$ as same as C' during the guidance process by themselves, then the medical guidance process must be continued or may be lost. That is:

$$\text{At } P(s) : \exists C', \text{ and } C' \neq T, \text{ then } \rightarrow \Phi.$$

- They get the initial guidance information clue C at the starting point $P(s)$, while there is interference Z on the path L_n, so they can not search the information clue T of target node $P(t)$ (content interference), then the medical guidance process must be continued or may be lost. That is:

$$\text{On the path } L_n : \exists Z, \text{ if } \overline{\exists} T, \text{ then } \rightarrow \Phi.$$

- They get the initial guidance information clue C at the starting point $P(s)$, but while there is interference Z in spatial structure CG of General Hospitals, so they can not search the information clue T of target node $P(t)$ (spatial interference), then the medical guidance process must be continued or may be lost. That is:

$$\text{In } CG : \exists Z, \text{ let } C \neq T, \text{ then} \rightarrow \Phi.$$

Due to the interference information Z in the spatial structure of General Hospitals, it will cause various interferences during the medical guidance process which make patients and relatives lost in the medical guidance. They must solve some problems such as resorting to the medical staff, which will seriously reduce the medical guidance efficiency.

72.2.4 *Classification of Medical Guidance Chains and Analysis of Medical-Guidance Cognitive Behavior in the Rational State*

Let the sequences consisting of all kinds of every medical node P_n and medical guidance path L_n in the spatial structure cognitive map CG of General Hospitals abstract regarded as every medical guidance chains. Patients and relatives get the initial guidance information clue C at the starting point $P(s)$, then they guide by themselves in medical guidance chains to find the medical guidance information clue T of target node $P(t)$, so the medical guidance chains are the main information media to find various departments and regions in General Hospitals.

Though the types of various medical guidance chains in the spatial structure of General Hospitals are different, there are mainly two types: straight and curved chain. The paper uses cognitive psychology and Shannon entropy function method to analyze the guidance cognitive behavior for all kinds of medical guidance chains combined with these two categories.

(1) Straight Chain

The medical guidance path between two nodes is straight, which can be classified as: visible straight chain (short chain) and non-visible chain (long chain).

① Visible Straight Chain (Short Chain)

Patients and relatives get the initial guidance information clue C at the starting point $P(s)$ of straight chain, and can search the guidance information clue T at the target node $P(t)$ within normal line of sight, namely $C \equiv T$. The scenario feature of straight chain generally will lead to backup avoidance effect, so it will form and keep the default values of the characterization schema for C. Event reaching $P(t)$ successfully one time is determined, in which they can solve the problem of their spatial location, thus the medical guidance will be fast and high efficient. At this moment, based on Shannon information entropy function, the uncertain H of the initial guidance information clue C is:

$$H = -\sum_{i=1}^{n} P_{r+i} \log p_{r+i}. \tag{72.3}$$

② Non-Visible Chain (Long Chain)

Patients and relatives get the initial guidance information clue C at the starting point $P(s)$ of straight chain, and because of middle node $P(m)$ or interference node $P(i)$ they can not search the guidance information clue T at the target node $P(t)$ within normal line of sight, namely $\overline{\exists} T$. So that they must take the difference reduction principle and try to move forward for searching T constantly. However, this difference reduction process (Hill climbing operator) cannot ensure they can search T or reach $P(t)$ successfully, namely, they can continue moving forward until they reach the target node or go back and get guidance lost. Meanwhile, this process will continue to use means-ends analysis attempt to create a new way to obtained information clue T, such as consulting medical staff. This will cause the hesitancy of medical guidance, namely lost of going back. The speed and efficiency of medical guidance are reduced. Event reaching $P(t)$ one time is not determined and it is hard to solve the problem of their spatial location. The uncertain H of the initial guidance information clue C is:

$$H = -\sum_{i=1}^{n} P_{r+i} \log P_{r+i} = -0.5 \log 0.5 - 0.5 \log 0.5 = 0.301. \tag{72.4}$$

Table 72.2 Classification and uncertainty analysis of the guidance cognitive behavior for the medical guidance chains

Classification	Judgment node (Interference node)	Information uncertainty H	Medical guidance behavior	Medical guidance results
Straight chain	Visible straight chain (short chain)	0	Certain	Reaching target node
	Non-visible straight chain (long chain)	0.301	Uncertain	Lost or reaching target node
Curved chain	Short chain, curved place $C \equiv T$	0	Certain	Reaching target node
	Short chain, curved place $C \neq T$	0.301	Uncertain	Lost or reaching target node
	Long chain, curved place $C \equiv T$	0.301	Uncertain	Lost or reaching target node
	Long chain, curved place $C \neq T$	0.477	Especially uncertain	Lost
Branch chain	The place of two–branches $C \equiv T$	0	Certain	Reaching target node
	The place of two–branches $C \neq T$	0.301	Uncertain	Lost or reaching target node
	Multi-branch chain	The rest can be referred	$\cdots$	Lost or reaching target node

(2) Curved Chain

The medical guidance path between two nodes is curved (turn around), which yet can be combined by straight chains. The scenario feature of curved chain means non-visible between two medical nodes and there are interference node $P(i)$ or middle node $P(m)$. The guidance cognitive behavior analysis about curved chain following Table 72.2.

72.2.5 *Guidance Information Carrier of Medical Guidance Chain: Sign or Kanban*

Another factor influencing the medical-guidance cognitive behavior of patients and relatives in General Hospitals is medical guidance information carrier: Sign or Kanban. Now at some medical node P_n and medical guidance path L_n in medical guidance chains the General Hospitals have generally been set the medical guidance system of Sign or Kanban which are the simplest, most direct medical guidance tools that can help the medical guidance mainly. From the view of psychology, the information collected by visual organs have the high memory value in human memory. Though there are some defects in the Sign or Kanban system, it usually is the first choice for the medical-guidance auxiliary method. The medical guidance information carriers setting unreasonable (missing) will also result medical guidance lost for patients and relatives. By using Set theory and graph theory this paper defines the information carrier structure model of medical guidance chain: Sign or Kanban model [5].

(1) Definition of Sign or Kanban Elements

Let f, v is the couple of information elements being ordered sequence for Sign or Kanban, and said {feature : value} is the information couple of Sign or Kanban, denoted as $\{f : v\}$, where f is called the attributes of information element content, v as the value of the information element content. The information couple $\{f : v\}$ can use to efficiently describe the content attributes of information elements for Sign or Kanban, such as $\{CT\text{check room} : 2\}$. Information couple is actually the concept of ordinal pair, the information with ordinal pair mode is very efficient in the visual sense.

(2) Structure Mode of Complete Information Collection for Sign or Kanban

By Set theory, let $C = \{fv\}$, the collection of information couple for Sign or Kanban, then in medical guidance chains the general structure mode of complete information collection for Sign or Kanban:

$$C = \left\{ \begin{array}{ll} C_0 & \leftarrow \text{top} \\ C_1, C_2, \ldots, C_n & \leftarrow \text{middle} \\ C_{11}, C_{12}, \ldots, C_{1n}, C_{21}, C_{22}, \ldots, C_{2n}, \ldots, C_{n1}, C_{n2}, \ldots, C_{nn} & \leftarrow \text{lower.} \end{array} \right. \tag{72.5}$$

C_0 is the top key (main) feature information element, which describes the key attribute of Sign or Kanban. All collection of each layer information elements describe the attribute of the information objects altogether for Sign or Kanban.

(3) Jigsaw Mode of Complete Information Structure for Sign or Kanban

According to graph theory, this paper constructs directed tree Jigsaw model of complete information structure for Sign or Kanban. C_0 on the top of the Jigsaw mode is the top key (main) feature information element. According to the importance of visual design principles with ergonomics and visual features which is top-down, left to right sight, the key information element C_0 should be arranged in the top horizon of Sign or Kanban (Fig. 72.1).

The each layer node n of structure mode of complete information collection and jigsaw mode of complete information structure for Sign or Kanban is positive integer, generally, $n \leq 6$. The n of each layer can be different, and all (the biggest) node N of information elements generally is: $N = 1 + 6 + 6 \times 6 = 43$.

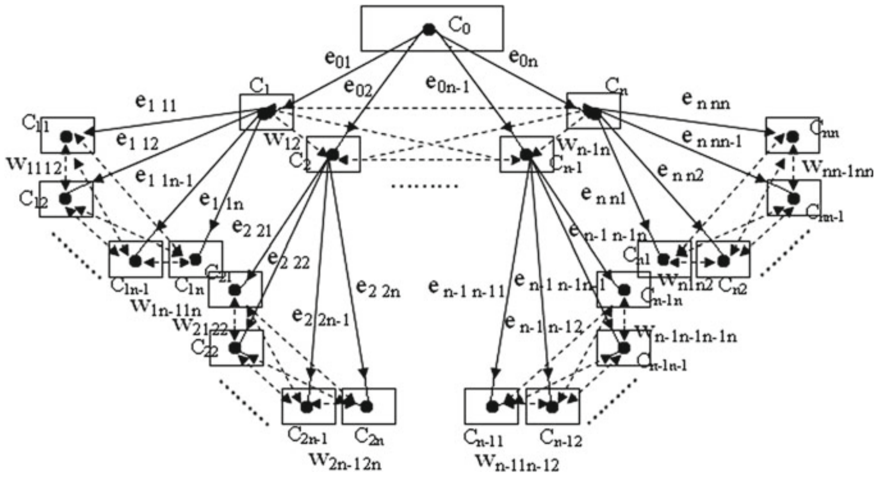


Fig. 72.1 Jigsaw mode of complete information structure for Sign or Kanban

72.2.6 Cognitive Behaviors Analysis of Sign or Kanban in Rational State

In the complex spatial structure of General Hospitals, patients and relatives generally search the medical guidance information carrier: Sign or Kanban at every medical node P_n and medical guidance path L_n of medical guidance chains to find related match information clue T of target node $P(t)$.

Analyzing structure mode of complete information collection and jigsaw mode of complete information structure for Sign or Kanban, the setting lack of each layer information element will also lead the uncertainty of medical-guidance cognitive behavior for patients and relatives, and there are several situations:

(1) Lack of the Top Key Feature Information Element C_0

If patients and relatives fail to search the top key feature information element C_0 in Sign or Kanban at every medical node P_n and medical guidance path L_n of medical guidance chains, namely C_0, even getting the information elements of the middle layer $\{C_1, C_2, \ldots, C_n\}$ and the bottom layer $\{C_{11}, C_{12}, \ldots, C_{nn}\}$, their cognitive behavior for Sign or Kanban is totally uncertain and their medical guidance gets lost, namely $\rightarrow \Phi$. At this moment, the event for reaching target node $P(t)$ one time is totally uncertain, and patients and relatives can not solve their spatial location problem, whose uncertain H of information collection C is 1.

(2) Lack of the Middle Layer Information Elements $\{C_1, C_2, \ldots, C_n\}$

Because of subordinated to the top key feature information element C_0, then even patients and relatives get C_0, they fail to search the middle layer information elements $\{C_1, C_2, \ldots, C_n\}(n \leq 6)$ in Sign or Kanban at every medical node P_n and medical guidance path L_n of medical guidance chains. This will increase the uncertainty of cognitive behavior for Sign or Kanban, and their medical guidance may be lost and difficult to solve their spatial location problem. The more lack of information elements in the middle layer, the more possibility in medical guidance lost. Theoretically, if lack of one information element in the middle layer, whose uncertainty H of information collection C is 0.280, the rest and so on.

(3) Lack of the Bottom Information Elements $\{C_{11}, C_{12}, \ldots, C_{nn}\}$

Because of subordinated to the middle layer information elements and describing their feature future, so patients and relatives fail to search the bottom information elements $\{C_{11}, C_{12}, \ldots, C_{nn}\}(n \leq 6)$ in Sign or Kanban at every medical node P_n and medical guidance path L_n of medical guidance chains. This will also increase the uncertainty of cognitive behavior for Sign or Kanban, but influence level is very little, and their medical guidance can not be lost nearly. Theoretically, if lack of one information element in the bottom layer, whose uncertainty H of information collection C is 0.054, the rest and so on.

72.3 Conclusion

This paper analyzes the potential medical guidance model, the uncertainty of guidance cognitive process and Sign or Kanban for the patients and relatives of General Hospitals in rational state, based on the cognitive psychology and the Shannon entropy function. It obtains the medical guidance principles of setting up medical guidance information system in General Hospitals, namely whole chain principle: patients and relatives can obtain complete medical guidance information clues C at the starting node $P(s)$, within normal line of sight they can continuously search the complete guidance information clue T (C_0 and C_n on Sign or Kanban should not be miss) at the next medical node or medical guidance path matching, until to the target node $P(t)$, and forming continuous complete medical guidance chain of medical guidance information, named as the complete information chain, or the whole chain. At this moment, the event which patients and relatives reach the target node is determined, and vice versa, medical guidance may be lost.

72.4 Limitations and Discussion

This paper mainly focus on the potential medical guidance model, the uncertainty of guidance cognitive process and Sign or Kanban for the patients and relatives of General Hospitals in rational state, but it lacks empirical validation about these theory hypothesis in the anxiety. Meanwhile, there is no more discussion of the medical guidance model, guidance cognitive process of medical multi-nodes and medical guidance multi-paths (such as multi-turns). In spite of this, this paper explores the theory of how to solve the scientific problem of complex spatial location in General Hospitals, and therefore, it is important in theoretical significance.

References

1. Cheng K, Pérez-Kriz S (2014) Map design for complex architecture: a user study of maps and wayfinding. Visible Lang 48(2):6
2. Devlin AS (2014) Wayfinding in healthcare facilities: contributions from environmental psychology. Behav Sci 4(4):423–436
3. Huelat BJ (2007) Wayfinding: design for understanding. The Center for Health Design, Concord
4. Kim MJ, Xea W (2015) Implementing an augmented reality-enabled wayfinding system through studying user experience and requirements in complex environments. Vis Eng 3(1):1–12
5. Li Y (2008) Research on the method of enterprise resource identification. Econ Manag 9:91–95
6. Rooke CN, Koskela L, Tzortzopoulos P (2010) Achieving a lean wayfinding system in complex hospital environments: design and through-life management. In: Proceedings of the 18th annual conference of the international group for lean construction. National Building Research Institute, Technion–Israel Institute of Technology, pp 233–242
7. Ulrich RS, Zimring C (2008) A review of the research literature on evidence-based healthcare design. HERD Health Environ Res Des J 1(3):61–125
8. Yuan L (2009) Building scientific guidance system for hospital. China Hospital CEO

Chapter 73
Upper and Lower Bounds to a Class of Degenerate Parabolic Equation with Time Dependent Coefficients

Anyin Xia, Xianxiang Pu and Shan Li

Abstract This paper is concerned with the blow-up solution of the degenerate parabolic equation with time dependent coefficients.

$$u_t = \Delta u^m + f(t)u^p,$$

under homogeneous Dirichlet boundary conditions, where $\Omega \subset \mathbb{R}^N$ is a bounded domain with smooth boundary $\partial\Omega, m > 1, p \geq m$. Firstly, blow-up solution is established for $p \geq m$ and furthermore, by virtue of some differential inequality, we obtain upper bound. In addition, a lower bound for the blow-up time is obtained under some appropriate hypotheses as long as blow-up occurs.

Keywords Degenerate parabolic equation · Global existence · Blow-up · Upper bound · Lower bound

2000 Mathematics Subject Classification 35K20 · 35K55 · 35K65 · 80M35

A. Xia
School of Science, Xihua University, Chengdu 610039,
People's Republic of China

A. Xia
Department of Mathematics, Sichuan University, Chengdu 610064,
People's Republic of China

X. Pu
Sichuan Sanhe College of Professionals, Luzhou 646200,
People's Republic of China

S. Li (✉)
Business School, Sichuan University, Chengdu 610064,
People's Republic of China
e-mail: lishan@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_73

73.1 Introduction and Main Results

In this work, we consider the following degenerate parabolic equation with time dependent coefficients under homogeneous Dirichlet boundary condition

$$\begin{cases} u_t = \Delta u^m + f(t)u^p & (x,t) \in \Omega \times (0,T), \\ u(x,t) = 0, & (x,t) \in \partial\Omega \times (0,T), \\ u(x,0) = u_0(x), & x \in \Omega, \end{cases} \tag{73.1}$$

here $\Omega \subset \mathbb{R}^N$ is a bounded domain with smooth boundary $\partial\Omega$, $m > 1$, $p \geq m$. $f(t)$ is a positive continuous function for any $t \geq 0$. The initial value $u_0(x)$ is nontrivial nonnegative continuous function and vanishes on $\partial\Omega$.

Global existence and singularity analysis of the solutions to the nonlinear parabolic equation have been investigated in the past decade, please see the famous surveys [1, 14]. The aim of this paper is to investigate the solution which blows up in finite time and estimate the life span of the singular solution. To evaluate the blow-up time is an interesting research topic in this field.

In [13], Payne and Philippin have considered the linear diffusion case, namely $m = 1$. However, the degenerate diffusion makes the present problem more complicated and takes more essential difficulties here. We would like to refer some results on blow-up solutions to the degenerate parabolic equations and system in [2–6] and references therein.

Many physical phenomena have formulated into similar mathematical models [2–9, 12, 14–16].

Recently, in [17], we give some results on the global existence and blow-up of the classical solutions to the boundary value problem (73.1):

(1) If $p < m$, then every classical solution to the problem (73.1) is global.

(2) If $p \geq m$, $\underline{k} := \inf f(t) > 0$, then the classical solution to the problem (73.1) blows up in finite time for large data $u_0(x)$.

In [19], we studied the global existence and the blowup solution to the following boundary-initial value problem

$$\begin{cases} u_t = \Delta u^m + f(t)g(u) & (x,t) \in \Omega \times (0,T), \\ u(x,t) = 0, & (x,t) \in \partial\Omega \times (0,T), \\ u(x,0) = u_0(x), & x \in \Omega. \end{cases} \tag{73.2}$$

In [18], we considered the following coupled system

$$\begin{cases} u_t = \Delta u^m + f_1(t)v^p, & (x,t) \in \Omega \times (0,T), \\ v_t = \Delta v^n + f_2(t)u^q, & (x,t) \in \Omega \times (0,T), \\ u(x,t) = v(x,t) = 0, & (x,t) \in \partial\Omega \times (0,T), \\ u(x,0) = u_0(x), \quad v(x,0) = v_0(x), & x \in \Omega, \end{cases} \tag{73.3}$$

and obtained the global existence and blow-up results to the boundary value problem (73.2) and (73.3).

In the following theorem, we give the blow-up result and obtain the upper bound for the blow-up time.

Theorem 73.1 *If $p \geq m$, $\underline{k} := \inf f(t) > \lambda_1$, then the classical solution to the problem (73.1) blows up in finite time T for large data $u_0(x)$, where λ_1 is the first eigenvalue to following problem*

$$\begin{cases} \Delta\varphi + \lambda\varphi = 0, & x \in \Omega, \\ \varphi = 0, & x \in \partial\Omega, \end{cases} \tag{73.4}$$

with $\varphi > 0$ $(x \in \Omega)$ and $\int_\Omega \varphi dx = 1$. Moreover, there exists a constant T_1, which depends on m, p, f, $u_0(x)$, such that $T \leq T_1$.

Furthermore, we give the following lower bound estimate to the blow-up time T.

Theorem 73.2 *Suppose that Ω be a convex domain in $\mathbb{R}^3$, the solution to the problem (73.1) blows up in finite time T, then there exists a constant T_0, which depends on m, p, f, $u_0(x)$, such that $T \geq T_0$.*

Remark 73.1 The results in Theorem 73.2 still hold for two-dimensional case. And the lower bound estimate to the blowup time is valid without the convex condition on the domain Ω.

The remain of this paper is organized as follows. In Sect. 73.2, we show that the classical solution to the problem (73.1) will blow up in finite time for some large initial data and show Theorem 73.1. In the last section, with aid of the differential equality, we will establish lower estimate to the blow-up time and show Theorem 73.2.

73.2 Upper Bound to the Blowup Time

In this section, we will discuss upper bound to the blow-up time under some appropriate hypotheses and show the Theorem 73.1.

Proof Denote

$$F(t) = \int_\Omega u\varphi dx. \tag{73.5}$$

Case 73.1 $p > m > 1$.

Combining (73.1) and (73.5), we have

$$F'(t) = \int_\Omega [\Delta u^m + f(t)u^p]\varphi dx \geq -\lambda_1 \int_\Omega u^m \varphi dx + \underline{k} \int_\Omega u^p \varphi dx. \tag{73.6}$$

As $p > m > 1$, making use of Hölder's and Young's inequality, we have

$$\int_\Omega u^m \varphi dx \le \left(\int_\Omega u\varphi dx\right)^{\frac{p-m}{p-1}} \left(\int_\Omega u^p \varphi dx\right)^{\frac{m-1}{p-1}} \\ \le \frac{p-m}{p-1}\int_\Omega u\varphi dx + \frac{m-1}{p-1}\int_\Omega u^p\varphi dx, \tag{73.7}$$

and

$$\int_\Omega u^p \varphi dx \ge \left(\int_\Omega u\varphi dx\right)^p. \tag{73.8}$$

Applying Eqs. (73.5)–(73.8), we obtain the inequality

$$F'(t) \ge -C_1 F(t) + C_2 F^p(t), \tag{73.9}$$

where $C_1 = \lambda_1 \frac{p-m}{p-1}$, $C_2 = \underline{k} - \lambda_1 \frac{m-1}{p-1} > 0$.

When $u_0(x)$ is a large data, we can obtain

$$C_2 F^{p-1}(0) - C_1 > 0. \tag{73.10}$$

So, we conclude that $F(t)$ is increasing monotonously for any $t > 0$.

Moreover, according Eq. (73.9) and $p > 1$, we can obtain that there exist $T > 0$, such that

$$\lim_{t\to T} F(t) = +\infty, \tag{73.11}$$

and

$$T \le \int_{F(0)}^{+\infty} \frac{d\tau}{-C_1\tau + C_2\tau^p} < +\infty. \tag{73.12}$$

Case 73.2 $p = m > 1$.

According to Eqs. (73.1) and (73.5), we can obtain

$$F'(t) = \int_\Omega \varphi[\Delta u^m + f(t)u^p]dx \ge (\underline{k} - \lambda_1)\int_\Omega u^p \varphi dx. \tag{73.13}$$

Moreover, applying $p > 1$, we have

$$\int_\Omega u^p \varphi dx \ge (\int_\Omega u\varphi dx)^p. \tag{73.14}$$

Combining Eqs. (73.13) and (73.14), we obtain the inequality

$$F'(t) \geq C_3 F^p(t), \tag{73.15}$$

where $C_3 = \underline{k} - \lambda_1 > 0$.

When $u_0(x)$ is a large data, we can obtain

$$F^{p-1}(0) > 0. \tag{73.16}$$

Thus we conclude that $F(t)$ is increasing monotonously for any $t > 0$.

Furthermore, according $p > 1$, Eqs. (73.15) and (73.16), we can obtain that there exist $T > 0$, such that

$$\lim_{t \to T} F(t) = +\infty, \tag{73.17}$$

and

$$T \leq \int_{F(0)}^{+\infty} \frac{d\tau}{C_3 \tau^p} < +\infty. \tag{73.18}$$

Let

$$T_1 = \min\left\{\int_{F(0)}^{+\infty} \frac{d\tau}{-C_1\tau + C_2\tau^p}, \int_{F(0)}^{+\infty} \frac{d\tau}{C_3\tau^p}\right\}, \tag{73.19}$$

the blow-up time T satisfy

$$T \leq T_1. \tag{73.20}$$

To sum up, Theorem 73.1 holds.

73.3 Lower Bound to the Blow-Up Time

In this section, we will give the lower bound to the blow-up time as long as blow-up occurs and show the Theorem 73.2.

Proof Firstly, denote

$$\Gamma(t) = \int_{\Omega} u^{2ms+m+1} dx, \tag{73.21}$$

where $s > 0$ will be fixed later. We compute

$$\begin{aligned}\Gamma'(t) &= (2ms+m+1)\int_\Omega u^{2ms+m}[\Delta u^m + f(t)u^p]dx \\ &= -\frac{(2ms+m+1)(2s+1)}{m(s+1)^2}\int_\Omega |\nabla u^{m(s+1)}|^2 dx + (2ms+m+1)f(t) \\ &\quad \int_\Omega u^{2ms+m+p}dx.\end{aligned} \tag{73.22}$$

Obviously, making use of Hölder's inequality, we have

$$\begin{aligned}f(t)\int_\Omega u^{2ms+m+p}dx &\le f(t)\left(\int_\Omega u^{2(2ms+m)}dx\right)^{\frac{1}{2}}\left(\int_\Omega u^{2p}dx\right)^{\frac{1}{2}} \\ &\le f(t)\left(\int_\Omega u^{6m(s+1)}dx\right)^{\frac{2ms+m-1}{2(4ms+5m-1)}} \\ &\quad \left(\int_\Omega u^{2ms+m+1}dx\right)^{\frac{ms+2m}{4ms+5m-1}}\left(\int_\Omega u^{2p}dx\right)^{\frac{1}{2}}.\end{aligned} \tag{73.23}$$

Applying Sobolev inequality [1] in $\mathbb{R}^3$

$$\left(\int_\Omega \zeta^6 dx\right)^{\frac{1}{6}} \le 4^{\frac{1}{3}}3^{-\frac{1}{2}}\pi^{-\frac{2}{3}}\left(\int_\Omega |\nabla\zeta|^2 dx\right)^{\frac{1}{2}},$$

we can obtain

$$\int_\Omega u^{6m(s+1)}dx \le \frac{16}{27\pi^4}\left(\int_\Omega |\nabla u^{m(s+1)}|^2 dx\right)^3. \tag{73.24}$$

Substituting (73.24) into (73.23) yields

$$\begin{aligned}&f(t)\int_\Omega u^{2ms+m+p}dx \\ &\le f(t)\left(\frac{2\sqrt[3]{2}}{3\pi\sqrt[3]{\pi}}\varepsilon\int_\Omega |\nabla u^{m(s+1)}|^2 dx\right)^{\frac{3(2ms+m-1)}{2(4ms+5m-1)}} \\ &\times\left\{\varepsilon^{-\frac{3(2ms+m-1)}{2ms+7m+1}}\left(\int_\Omega u^{2ms+m+1)}dx\right)^{\frac{2ms+4m}{2ms+7m+1}}\left(\int_\Omega u^{2p}dx\right)^{\frac{4ms+5m-1}{2ms+7m+1}}\right\}^{\frac{2ms+7m+1}{2(4ms+5m-1)}} \\ &\le \frac{\sqrt[3]{2}(2ms+m-1)}{\pi\sqrt[3]{\pi}(4ms+5m-1)}\varepsilon\int_\Omega |\nabla u^{m(s+1)}|^2 dx \\ &+\frac{2ms+7m+1}{2(4ms+5m-1)}\varepsilon^{-\frac{3(2ms+m-1)}{2ms+7m+1}}\left(\int_\Omega u^{2ms+m+1}dx\right)^{\frac{2ms+4m}{2ms+7m+1}}\left[f^2(t)\int_\Omega u^{2p}dx\right]^{\frac{4ms+5m-1}{2ms+7m+1}} \\ &\le \frac{\sqrt[3]{2}(2ms+m-1)}{\pi\sqrt[3]{\pi}(4ms+5m-1)}\varepsilon\int_\Omega |\nabla u^{m(s+1)}|^2 dx\end{aligned}$$

$$+\frac{2ms+7m+1}{2(4ms+5m-1)}\varepsilon^{-\frac{3(2ms+m-1)}{2ms+7m+1}}\left(\int_\Omega u^{2ms+m+1)}dx\right)^{\frac{2ms+4m}{2ms+7m+1}} f(t)^{\frac{2(4ms+5m-1)}{2ms+7m+1}}$$
$$\times\left(\int_\Omega u^{2ms+m+1}dx\right)^{\frac{2p(4ms+5m-1)}{(2ms+7m+1)(2ms+m+1)}}|\Omega|^{1-\frac{2p}{2ms+m+1}}, \tag{73.25}$$

where $\varepsilon = \frac{\pi\sqrt[3]{\pi}(2s+1)(4ms+5m-1)}{\sqrt[3]{2}m(s+1)^2(2ms+m-1)}$, and $s > \frac{p}{m} - \frac{1}{2} - \frac{1}{2m}$.

Let $s = \frac{p}{m}$, and substituting (73.25) into (73.22), we have

$$\Gamma'(t) \le k(t)\left(\int_\Omega u^{2ms+m+1}dx\right)^{\mu_1+\mu_2} = k(t)\Gamma^{\mu_1+\mu_2}(t), \tag{73.26}$$

where

$$k(t) = (2p+m+1)\frac{2p+7m+1}{2(4p+5m-1)}\varepsilon^{-\frac{3(2p+m-1)}{2p+7m+1}}|\Omega|^{1-\frac{2p}{2p+m+1}} f(t)^{\frac{2(4p+5m-1)}{2p+7m+1}} > 0,$$

and

$$\mu_1 = \frac{2p+4m}{2p+7m+1} > 0, \quad \mu_2 = \frac{2p(4p+5m-1)}{(2p+m+1)(2p+7m+1)} > 0.$$

If we suppose that

$$\lim_{t\to T}\Gamma(t) = +\infty \quad (0 < T < +\infty), \tag{73.27}$$

then there exists $t_1 > 0$ such that $\Gamma(t) > 1 (t > t_1)$.

Integrating Eq. (73.26) from t_1 to T, we obtain

$$\int_1^{+\infty}\frac{d\Gamma}{\Gamma^{\mu_1+\mu_2}} \le \int_{t_1}^T k(t)dt \le \int_0^T k(t)dt. \tag{73.28}$$

Let $\Theta(T) = \int_0^T k(t)dt$. Obviously, $\Theta(T)$ is increasing monotonously. So we can obtain

$$T \ge \Theta^{-1}(\alpha) := T_0 > 0, \tag{73.29}$$

where $\alpha = \int_1^{+\infty}\frac{d\Gamma}{\Gamma^{\mu_1+\mu_2}}$, Θ^{-1} is the inverse function of Θ, and $T_0 = T_0(m, p, u_0(x), f(t))$.

So, Theorem 73.2 holds.

Remark 73.2 Motivated by the present work, we will investigate the global solution and the blow-up analysis of the parabolic system with general nonlinear source terms,

$$\begin{cases} u_t = \Delta u^m + f_1(t)g_1(v), & (x,t) \in \Omega \times (0,T), \\ v_t = \Delta v^n + f_2(t)g_2(u), & (x,t) \in \Omega \times (0,T), \\ u(x,t) = v(x,t) = 0, & (x,t) \in \partial\Omega \times (0,T), \\ u(x,0) = u_0(x), \quad v(x,0) = v_0(x), & x \in \Omega, \end{cases} \tag{73.30}$$

where $\Omega \subset \mathbb{R}^N$ is a smooth bounded domain, $m, n > 1$. The coefficient $f_1(t)$, $f_2(t)$ are positive continuous functions for any $t > 0$. The nonlinearity $g_1(v)$, $g_2(u)$ are assumed to satisfy $g_1(v) > 0 (v > 0)$, $g_2(u) > 0 (u > 0)$ and $g_1(0) = g_2(0) = 0$. The initial value $u_0(x)$, $v_0(x)$ are nontrivial nonnegative continuous functions and vanish on $\partial\Omega$. The similar results will be obtained in our forthcoming work.

References

1. Bandle C, Brunner H (1998) Blowup in diffusion equations: a survey. J Comput Appl Math 97(1–2):3–22
2. Du L (2006) Blow-up for a degenerate reaction-diffusion system with nonlinear localized sources. J Math Anal Appl 324(1):304–320
3. Du L (2007) Blow-up for a degenerate reaction-diffusion system with nonlinear nonlocal sources. J Comput Appl Math 202(2):237–247
4. Du LL, Mu F (2005) Global existence and non-existence for a quasilinear degenerate parabolic system with non-local source. Dyn Syst 20(4):401–412
5. Du L, Mu C (2005) Global existence and blow-up analysis to a degenerate reaction-diffusion system with nonlinear memory. Commun Pure Appl Anal 4(4):721–733
6. Fan M, Mu C, Du L (2007) Uniform blow-up profiles for a nonlocal degenerate parabolic system. Appl Math Sci 22(1–4):485–509
7. Friedman A, Mcleod B (1986) Blow-up of solutions of nonlinear degenerate parabolic equations. Arch Ration Mech Anal 96(96):55–80
8. Fujita H (1966) On the blowing up of solutions of the cauchy problem for $u_t = \delta u + u^{1+\alpha}$. Jfacsciunivtokyo 13:109–124
9. Hernndez J, Mancebo F, Vega J (2007) Positive solutions for singular nonlinear elliptic equations. Proc R Soc Edinb 137(137):41–62
10. Li F, Xie C (2003) Global existence and blow-up for a nonlinear porous medium equation. Appl Math Lett 16(2):185–192
11. Payne L, Philippin G (2013) Blow-up phenomena in parabolic problems with time dependent coefficients under dirichlet boundary conditions. Proc Am Math Soc 141(7):2309–2318
12. Payne LE, Philippin GA (2012) Blow-up phenomena for a class of parabolic systems with time dependent coefficients. Appl Math 03(4):325–330
13. Payne LE, Schaefer PW (2007) Lower bounds for blow-up time in parabolic problems under dirichlet conditions. J Math Anal Appl 328(2):1196–1205
14. Quittner P, Souplet P (2007) Superlinear parabolic problems. Birkhauser, Basel
15. Tan Z, Xu Y (2012) Existence and nonexistence of global solutions for a semi-linear heat equation with fractional laplacian. Acta Mathematica Scientia 32(6):2203–2210
16. Wiegner M (1997) A degenerate diffusion equation with a nonlinear source term. Nonlinear Anal 28(12):1977–1995
17. Xia AY, Pu XX, Li S (2015) Global existence and blow-up to a class of degenerate parabolic equation with time dependent coecients. Adv Eng Res, 1592–1595
18. Xia AY, Pu XX, Li S (2016) Global existence and nonexistence for a class of parabolic systems with time-dependent coefficients. Boundary Value Problems 28
19. Xia AY, Pu XX, Li S (2016) Singularity analysis for a class of porous medium equation with time-dependent coefficients. Adv Math Phys

Chapter 74
Empirical Analysis on the Relationship Between Industrial Economy Growth and Environmental Pollution of Sichuan Province

Xinyi Li, Guangjin Li, Hong Wang and Baocai Fan

Abstract This paper investigates the cointegration relationship between industrial economic growth and environmental pollution of Sichuan province and further tests its Granger causality by using time series data of three typical pollution indicators. The co-integration analysis shows the above relationship may not be EKC, but linear and positive. Hence, it is hardly possible to turn the relationship negatively correlative by market adjustment itself. The result of Granger causality shows industrial economic growth is the Granger cause for the changes of environment quality but not vice versa. The reasons may include the failure of recent technology advances being reflected on lower pollution emission intensity, the absence of resource trading market and emission trading market and the lack of incentives of firms to manufacture environment-friendly.

Keywords Industrial economic growth · Environmental pollution emission · Cointegration test · Granger causality test

74.1 General Instructions

Environment and economy are interactional, resources plays a vital role in this system. Because the traditional model of economic growth is based on the overuse of natural resources and exploitation of environment capacity, massive pollution that caused degeneration of environment quality is produced when economy keeps growing in this way. And in reverse the economic growth may be hindered by the accelerated resource depletion and deteriorated environment capacity. Many researchers discussed the relationship between economic growth and environmental pollution

X. Li (✉) · G. Li · H. Wang · B. Fan
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 2401155968@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_74

and the most typical research among them is the Environmental Kuznets Curve (EKC) [12, 13, 24].

EKC research on income distribution and economic growth indicates that "inverted U-shaped" index can describe the relationship between environment quality and economic growth. At the early stage of economic development, economic growth is achieved at the expense of sacrificing the environment capacity and the output increase is accompanied by environmental quality degradation. However, as the economic growth exceeds a certain threshold level, the output increase will be synchronized to environmental quality improvement [2, 22, 23]. After Grossman and Krueger [6, 7, 15] explained the EKC with scale, structure and technology effect, numerous studies conducted "inverted U-shaped" curve empirical analysis [4, 5, 17, 18, 20, 21].

Many empirical results do not support the hypothesis of the "inverted U-shaped" relationship between environmental quality and economic growth. For example, Inmaculate [17] found an "N-shaped" relationship between GDP and carbon dioxide emissions based on the panel data constituted by 22 OECD countries. Meanwhile, Negative changes in environmental quality may be counterproductive to economic growth. Lopez [2, 16] included the depletion of resources and environmental quality into the neoclassical growth model, equivalent to material and labor input elements in the traditional production function, and discussed optimal endogenous growth issues with natural resource input factors.

Other documents include pollution quantity or stock in the consumer's utility function and investigate Issues of inter-temporal decisions of consumers in a standard Ramsey–Koopmans–Cass theoretical framework of economic growth. It shows that environmental quality has been considered as an factor on optimal choices of consumer in the theoretical framework of social welfare analysis.

In China, the research on the counterproductive effect of the changes of environment on economic growth is still at an initial stage. Peng [19] studied a two-way dynamic relationship between environmental pollution and income changes based on the panel data of China's six major categories of environmental pollution indicators. Li and Zhou [14] used an empirical analysis by selecting 1981–2009 per capita GDP of Shandong Province and measuring the level of environmental pollution data, and they established VAR model on economic growth and environmental pollution, using generalized impulse response analysis and variance decomposition of economic growth indexes to measure the dynamic relationship between economic growth and different environment pollution levels Different from the previous studies, this paper firstly discusses whether a long term stable correlation exits between industrial growth and environmental pollution of Sichuan province, namely a cointegration analysis, and then goes further to Granger causality test to analyze their relationship. It adds enormous value to the environment and economy study via empirical research and provides pragmatic, accurate and useful suggestions on how Sichuan province shall properly deal with the relationship between its economic development and environmental quality.

74.2 Method

74.2.1 Co-integration Test

This part discusses the long-term stable relationship between industrial growth and environmental pollution with co-integration test based on VAR method by Johansen [9, 10] and Juselius [11]. The key part of Johansen's co-integration test is to calculate two statistics. One of them is trace statistic:

$$\lambda_{\text{tace}} = -T\sum_{i=r+1}^{n}\ln(1-\hat{\lambda}_{r+1}),\ \ r=0,1,\ldots,n-1,$$

where $r = No.\ r$ characteristic roots; $\lambda =$ Eigenvalues of the remaining matrix by maximum likelihood estimation method.

The other is the largest eigenvalue statistic, which is the likelihood ratio statistic to examine the zero value of $r+1$ eigenvalue:

$$\lambda_{\max} = -T\ln(1-\hat{\lambda}_{r+1}),\ \ r=0,1,\ldots,n-1.$$

The test results of the above two statistics are used to determine whether same random trend exists between the variables.

74.2.2 Granger Causality Test

General regression models allow k additional predictors:

$$\begin{aligned}Y_t =& \beta_0+\beta_1Y_{t-1}+\beta_2Y_{t-2}+\beta_pY_{t-p}+\delta_{11}Y_{1t-1}+\delta_{12}Y_{1t-2}+\cdots+\delta_{1q_1}Y_{1t-q_1}+\cdots\\ &+\delta_{k1}Y_{kt-1}+\cdots+\delta_{\text{kpt}}Y_{kt-qk}+u_t.\end{aligned}$$

Granger causality statistic is the F statistic of zero hypothesis that tests the zero value of all coefficients of a variable in the formula above. The zero hypothesis implies that these regressions do not predict factor Y_t (except predictions contained in other regression factors) and its test is named Granger causality test. The paper uses this method to test the two-way causal relationship between economic growth and environmental quality.

74.3 Empirical Analysis

74.3.1 Data Resources

This study selects industrial GDP as an indicator of the industrial economy, with per capita emissions of industrial wastewater, waste gas and solid waste as three indicators of the degree of environmental degradation.

There are three reasons for using these three indicators. Firstly, waste water, waste gas and waste solid are universally acknowledged as three major sources of pollution, this classification is adopted by China in every level of environmental evaluation and policy formulation. Secondly, most domestic and international studies directly select indicator value of environmental degradation, but do not take into account the potential impact of population growth on environmental changes. The impact of population on environment is tremendous; the existence of human beings constantly requires consumption of natural resources to feed the very basic needs. As population grows, megacities and big towns comes into being, they are consuming natural resources in a larger scale by developing industry which can be pollutant to support more citizens. In order to avoid the exogenous impact by population changes on environmental pollution, per ca-pita indicator value is adopted since it reflects the dynamic between population and environmental changes and thus makes the test more convincing. Thirdly, because Chinese government and NGOs are using the three factors for a long time, the data can be traced back decades ago and the resources are more variable and reliable. The timing dimension of this data analysis in this study is from 1990 to 2010, with data sources collected and calculated from "China Statistical Yearbook" and "Sichuan Statistical Yearbook" of various years. See Table 74.1.

Table 74.1 Names, units and symbols of various types of analysis factor

No.	Name of factors	Unit (unit/year)	Symbol by the paper
1	Per ca-pita emission of industrial waste water	Ton/per person	Per water
2	Per ca-pita emission of industrial waste gas	M^3/per person	Per smoke
3	Per ca-pita emission of industrial solide waste	Ton/per person	Per solide
4	Per ca-pita emissions of 'three wastes'	–	Per Z
5	Industrial output	100 million Yuan	Ind GDP

74.3.2 *Co-Integration Analysis of the Effect of Industrial Economy on Environmental Pollution*

(1) Unit Root Tests

Before co-integration analysis, the single integration order of the variables in the model must be clarified if the sequence has a non-stationary line, difference must be made to get smooth data and then co-integration test and impulse response analysis can be further conducted. The paper firstly uses ADF (Augmented Dickey–Fuller) method to make smooth test on variable sequences of Per Water, Per Smoke, Per solide, Ind GDP and their first differences of Δ Per Water, Δ Per Smoke, Δ Per solide and Δ Ind GDP respectively. Then the single integration order of the variables is determined according to the test results. ADF test results see Table 74.2.

C, T and N denote the constant figure, time trend and lag period of time respectively in the test status. ADF requires the most complicated status shall be tested first. That is, test with the constant term and time trend is made first, then lag term is included to make the residual white noise. The optimal lag period is selected follow-ing AIC value minimum standard. "–" means failure to ADF test, "***", "**", "*" means significant at 1, 5 and 10 % confidence level respectively.

The test results listed by Table 74.2 shows that variable consequence of Per Water, Per Smoke, Per solide and Ind GDP is non-stationary. The stationary sequence of I∼ [1] is achieved by first difference. This creates the basis for further inter-variable co-integration test.

(2) Co-Integration Analysis

The way to conduct the co-integration analysis is to use the eigenvalues track testing method by Johansen to do the test on sequence Per Z and Ind GDP respectively. Constant and (or) time trend are considered when doing the tests. The test results see Table 74.3.

Table 74.3 shows the results of the co-integration test based on the VAR model illustrates a long term linear correlation both in Δ In Z and Δ In GDP when the endogenous bias is removed and all the pollution variables are positively correlative.

Table 74.2 ADF unit root test results

Variables	Test status	Test results with different threshold
Per water	C, T, 1	–
Δ Per water	C, T, 2	***
Per smoke	C, T, 2	–
Δ per smoke	C, T, 1	**
Per solide	C, T, 1	***
Δ per solide	C, T, 2	**
Ind GDP	C, T, 2	–
Δ ind GDP	C, T, 2	***

Table 74.3 Per Z and Ind GDP co-integration test result

Pollution variable	Lag period of time	Different threshold	Fitting category	Co-integration relationship
Per water	1	**	A linear	Positive correlation
Per smoke	1	**	A linear	Positive correlation
Per solide	1	***	A linear	Positive correlation

The positive co-integration relationship between the changes of the industrial GDP of Sichuan province and its effect on pollution variable is different from the previous study results by Grossman and Krueger [6] etc. The industrial economy of Sichuan Province and its indicators of environmental pollution shows a linear relationship, not EKC.

In fact, EKC only reflects one of the various possible relationships between economic growth and environmental indicators, but the relationship between environment and economic growth is more complicated than that described in the model as some of the literature [1, 3, 21] points out, EKC simply describes their relationship according to common experience and the analysis process itself is not so stringent. Changes in people's behavior and preferences, institutional changes, technological and organizational changes, structural changes etc. all may be important factors. And besides, different sample range and different models may have different results. Since the analytic technique used in this paper is different from the previous studies which use cross-sectional data of the countries, the economic implication of the economy-environment relationship illustrated by the paper is also differentiated. That is, the empirical results by the sample of Sichuan province do not support the general EKC rule of the inverted U-shaped relationship between environment and economic changes, but co-integration test shows a positive linear correlation between them. Although co-integration test does not approve the conclusion of EKC relationship between environmental pollution and industrial economy, it should be understood first of all the EKC is just a empirical description of the relationship between economic growth and environmental indicators. The co-integration test concludes that "U-shape" index cannot describe the relationship between economic growth and environment indicators, there would be no "turning point" since their relationship is described by a line. The co-integration test concludes that "U-shape" index cannot describe the relationship between economic growth and environment indicators; there would be no "turning point" since a line describes their relationship.

Hence, Factors like self-regulation of market or self-consciousness of individuals can hardly make them negatively correlative, it is more about the original greed that drive people to consume environment and mobilize economic growth to improve their living quality. Green economy in this area is still something in the future, something after people are traumatized by hazardous environment disasters. One thing that should be poured attention to is that the data used above is after all from a relatively short period of time. It takes the western world at least one hundred years to clean the sufferings of industrial development, China especially Sichuan which is at the backyard of China where the first and second industry is crucial to economic output, is at the very primary stage of industry development. The "turning point" might come when the technology advances, the manufacture lines are transferred to African or South-East Asia and people become conscious and active politically in environmental issue.

74.3.3 Granger Causality Test of Industrial Economy and Environmental Pollution

Correlation only shows synchronous features of how industrial economy and environment are changing, but the synchronization feature cannot be interpreted as causality. In order to test their two-way causal relationship from the statistical point of view, namely whether the change in the industrial economy is an important factor leading to changes in emissions, or on the contrary, whether the change in emissions causes industrial economy changes, the paper makes analysis by Granger causality test based on EMC model. The results see Table 74.4.

A conclusion can be drawn from the Table 74.4 test results: the analysis results from three indicators, which are most typical of environmental pollution, and the results from the sample time sequence and cross-sectional dimensions show that ind the change of ind GDP causes changes of environment quality.

All three pollution indicators are significant under 1 % confidence level at Granger causality test. Combined with the results of the co-integration analysis, it could be concluded that environmental pollution and industrial economy not only have a long-term correlative relationship, but also include an important content in this kind of relationship, namely, changes in the industrial economy will directly promote environmental quality change accordingly. The results show that the industrial growth in Sichuan province is still accompanied by the increasing environmental pollution Industrial pollution emission increase in unit directly improves the company's marginal savings, and with capital flocking to higher profit industry per its

Table 74.4 Granger causality test results based on EMC model

Pollution variable	Lag period of time	H0: ind GDP does not Granger cause Per Z	H0: Per Z does not Granger cause ind GDP
Per water	1	***	*
Per smoke	1	***	–
Per solide	1	***	–

characteristics, a positive correlation result is determined, namely, the marginal saving increase resulting from the expansion of heavily polluting industries.

Therefore, the empirical result of non-EKC relationship implies that we cannot take the EKC hypothesis as an excuse to the old development model of "treatment after pollution". Reducing pollutant emissions depends not only on external technical level (including general technology and sewage, pollution treatment technology), the key lies in whether the firms of micro economy have sufficient incentives and motivation to use environmentally friendly technology, as the latter tend to make profit-maximizing decisions. Rather than its relying only on future market self-regulation, government intervention is needed here. Government shall make proper policies for pollution treatment that not only provides support for the development of new and clean technologies, but also provides external incentives for micro-enterprises to promote the use of environmentally friendly technologies. Since most subjects in the market are profit driven, the very powerful way to change the vicious circle is to raise the cost of producing pollution. When they are doing the calculation in mind and realize that the old model of making profit would drag them into a rather poorer stage, they will actively seek for cleaner solutions.

It is also important to notice that Granger causality test of industrial economy and environmental pollution shows pollution indicators are not the reasons for ind GDP change. Even the Per Water statistic result appears to be significant under 10 % confidence level.

It could be interpreted in the following three points. Firstly, China's economic growth has been achieved at the expense of losing natural resources renewable capacity since the "reform and open" policy and the economy was propelled by continuous consumption of environmental capacity. In the whole process of economic development, technological advances, namely the improvement of green technologies, will not necessarily lead to lower emission intensity, but mostly focus on the technic development and innovation in lower production direct cost. Therefore, it is inevitable that the total economy is mobilized by the model of development that unstoppably exploit the environmental capacity. The economic growth of China falls into the description of the basic neo-classical economic development theory.

Secondly, The price mechanism cannot generate correct price signals to the market since individuals will not actively have consciousness to behave environment-friendly. As long as the negative externalities by production do not turn internal through an effective emission trading market, the pollution emission will not can hardly be reflected by economy growth. At present, China has implemented pilot emission trading in some cities. As it is only at an initial stage, emission trading market need improving. Government-commanded emission trading always failed to adjust the market to the normal track effectively, market-based solution is the more powerful weapon to regulate the economic behaviors and promote a green growth.

Finally, emission feedback mechanism of economic growth may also produce "green effect" for the brands of enterprise. Dasgupa [3, 8] stated different levels of pollutant emission by the companies actually helped to provide the capital market with the signals of different technical levels of these companies, which could affect their financial conditions. But in China, although the state has launched relevant green credit policy in recent years, the information is asymmetric among the local authorities, banks and firms since sometimes their benefits collide. Therefore, it is quite difficult for the banks to make accurate assessment on environment risk. For the purpose of economic growth, some local government may even ask the banks to provide loans to the companies that break environmental regulations. Local protectionism is an obstacle to "green credit" policy, when government is biased and sometimes violates the principles itself, the incentive of the enterprises to gain green credit is minimal, thus the system of green credit failed to function. It is also difficult to encourage the enterprise by the environmental counteraction effect because most firms are shortsighted and as long as the money the made is more than what they cost, they will not even change for a bit.

In addition, the change of people's preference to environmental quality may also be counterproductive in economic growth. Reduce of pollutant emission, as a clean environment conducive could be beneficial to lower the employee health loss and promote labor efficiency. But many Chinese companies do not attach enough importance to the potential benefits a cleaner environment may bring. If firms could realize how a clean environment could help to increase productivity this company and employee win-win way of business operation will be likely to achieve social Pareto improvement.

74.4 Conclusion

The paper takes an example of the relationship between industrial economy growth and environmental pollution of Sichuan province. It first tests whether co-integration can describe the relationship between industrial economy growth and environmental pollution. Then it analyzes whether the co-integration relationship is Granger causality and comes to the following conclusion.

Firstly, the co-integration analysis shows the empirical results do not support the normal EKC theory of a U-shaped relationship between environment and economy changes. In fact, EKC only reflects one of the various possible relationships between economic growth and environmental indicators, and their relationship is much more complicated than described in the model. Since the relationship between the current economic growth and the environmental quality is linear and positive, it is hardly possible to turn the relationship negatively correlative by market adjustment itself.

Secondly, based on the above cointegration relationship analysis, the paper tests its Granger causality. The result shows industrial economic growth is the Granger cause for the changes of environment quality, but the environment quality change is not the Granger cause for industrial economic changes. The reasons may include the failure of recent technology advances being reflected on lower pollution emission intensity, the absence of resources and emission trading market and the lack of effective incentives of green production to the firms. All these reasons will make external pressures on the transformation of the industrial growth model of China.

References

1. Arrow K, Bolin B, Rea C (1995) Economic growth, carrying capacity, and the environment. Science 268(5210):520
2. Bovenberg AL, Smulders SA (1996) Transitional impacts of environmental policy in an endogenous growth model. Science 37(4):861–893
3. Dasgupta S, Laplante B, Wang H (2002) Confronting the environmental kuznets curve. Science 16(1):147–168
4. Dinda S (2004) Environmental kuznets curve hypothesis: a survey. Science 49(4):431–455
5. Ekins P (1997) The kuznets curve for the environment and economic growth: examining the evidence. Science 29(5):805–830
6. Grossman G, Krueger A (1991) Environmental impacts of a north american free trade agreement. Technical report, National Bureau of Economic Research
7. Grossman G, Krueger A (1993) Environmental impacts of the north American free trade agreement., The US-Mexico Free Trade AgreementMIT Press, Cambridge
8. Gupta S, Goldar B (2005) Do stock markets penalize environment-unfriendly behaviour? evidence from India. Science 52(1):81–95
9. Johansen S (1988) Statistical analysis of cointegration vectors. Science 12(2):231–254
10. Johansen S (1991) Estimation and hypothesis testing of cointegration vectors in gaussian vector autoregressive models. Science 59:1551–1580
11. Johansen S, Juselius K (1990) Maximum likelihood estimation and inference on cointegration-with applications to the demand for money. Science 52(2):169–210
12. Lantz V, Feng Q (2006) Assessing income, population, and technology impacts on co 2 emissions in Canada: where's the EKC? Science 57(2):229–238
13. Li X, Hu H, Luo H (2015) Two-way coupling relationship between economic growth and environmental pollution-regional difference analysis based on pvar model. Science 6:1886–1985 (in Chinese)
14. Li Z, Zhou D (2013) An empirical analysis on the relationship between the economic growth and the environmental pollution based on var model. Science 8:11–16 (in Chinese)
15. Lin B, Jiang Z (2009) Chinese carbon dioxide environmental kuznets curve forecasting and influencing factors. Science 4:27–36 (in Chinese)
16. Lopez R (1994) The environment as a factor of production: the effects of economic growth and trade liberalization. Science 27(2):163–184
17. Martínez-Zarzoso I, Bengochea-Morancho A (2004) Pooled mean group estimation of an environmental kuznets curve for CO_2. Science 82(1):121–126
18. Panayotou T (2000) Economic growth and the environment. Center for International Development at Harvard University, Technical report
19. Peng S, Bao Q (2006) China's economic growth and environmental pollution-based on empirical analysis of time series data (1985–2003). Science 7:5–12 (in Chinese)
20. Selden T, Song D (1995) Neoclassical growth, the J curve for abatement, and the inverted U curve for pollution. Science 29(2):162–168
21. Stern D (1998) Progress on the environmental kuznets curve? Science 3(2):173–196
22. Stokey N (1998) Are there limits to growth? Science 39(1):1–31
23. Tahvonen O, Kuuluvainen J (1993) Economic growth, pollution, and renewable resources. Science 24(2):101–118
24. Zhou X (2014) Study on the relationship between economic growth and environment pollution from the perspective of industrial location quotient. Ph.D. thesis, (in Chinese)

Chapter 75
The Performance Evaluation of IURCI of Sichuan Provincial Strategic Emerging Industries

Xiaofeng Li, Qisheng Cheng and Xiaocan Su

Abstract Industry-University-Research collaborative innovation (IURCI) is not only a basic approach to improve industrial technology competence but also an important element of the national innovation system. The key of building an innovation-oriented country is to actively push forward the collaborative innovation among enterprises, universities and scientific research institutions. Based on matter-element and extension set theories, the extension matter-element model for the performance evaluation of Industry-University-Research collaborative innovation was established, and the specific method for performance evaluation was proposed. This method not only describes the various factor indexes that affect the Industry-University-Research collaborative innovation performance from a formal perspective, but also provides an accurate performance assessment. Relying on this method, the Industry-University-Research collaborative innovation performance of Sichuan provincial strategic emerging industries was evaluated as an empirical case study. According to the result analysis, the performance level and the main influencing factors of the Industry-University-Research collaborative innovation of Sichuan provincial strategic emerging industries were determined. Then, corresponding countermeasures and recommendations were put forward.

Keywords Strategic emerging industry · Collaborative innovation · Matter-element model · Performance evaluation

75.1 Introduction

Industry-University-Research collaborative innovation (IURCI), as a promotion model of social technology innovation, integrates the superior resources of enterprises, universities and research institutions [6]. This model not only can accelerate

X. Li · Q. Cheng · X. Su (✉)
School of Business, Sichuan University, Chengdu 610064,
People's Republic of China
e-mail: XiaocanSu@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_75

the conversion of scientific research achievements, improve the quality of scientific research, enhance economic and social benefits, but also can promote the development of college institutions, enterprises, local governments and other related parties, and thereby improve the innovation capability of the whole society [8].

Sichuan, as an important economic, industrial, and agricultural province, has the relative regional advantage, industrial advantage and market advantage in West China, the strategic position of Sichuan province is extremely important. In order to promote industrial restructuring and upgrading, Sichuan province has cultivated and developed six strategic emerging industries. The IURCI performance of these strategic emerging industries has become an important concern for the government, enterprises and academic community in Sichuan. In this regard, based on matter-element and extension set theories [9], this paper established the matter-element model to evaluate the IURCI performance, and proposed the specific method for performance evaluation. We apply this method to evaluate the IURCI performance of the strategic emerging industries in Sichuan province. On this basis, we put forward some countermeasures and recommendations to promote the IURCI in Sichuan.

The paper was organized as follows. In Sect. 75.2, the performance evaluation index system for IURCI was established. The matter-element model of IURCI performance evaluation was built in Sect. 75.3. The extension evaluation method for the performance evaluation of IURCI was proposed in Sect. 75.4. In Sect. 75.5, the IURCI performance of Sichuan provincial strategic emerging industries was evaluated as an empirical case study. Some concluding remarks are finally given in Sect. 75.6.

75.2 Establishment of the Performance Evaluation Index System for IURCI

In order to evaluate the Industry-University-Research collaborative innovation performance of strategic emerging industries, it is necessary to construct a performance evaluation index system for Industry-University-Research collaborative innovation.

Based on the input–output theory, the influencing factors for the IURCI performance are divided into three aspects: input, output and environment, as the first-class indexes of performance evaluation. Based on expert survey and references of relevant literatures [1–3, 5, 7, 10], a preliminary list of second-class indexes is obtained. Then, some second-class indexes are removed according to the results of questionnaire investigation and statistical analysis. The finalized performance evaluation index system for IURCI is established as shown in Table 75.1.

Table 75.1 The performance evaluation index system for IURCI

Evaluation object	Evaluation element	Evaluation index
The Industry-University-Research collaborative innovation performance	Input of Industry-University-Research collaborative innovation	Amount of funds x_1
		Talent input x_2
	Output of Industry-University-Research collaborative innovation	Number of innovations x_3
		Innovation diffusion x_4
		Transformation of innovative achievements x_5
	Environment of Industry-University-Research collaborative innovation	Policy environment x_6
		Economic environment x_7
		Technical environment x_8
		Financing environment x_9
		Educational environment x_{10}

75.3 The Matter-Element Model of IURCI Performance Evaluation

75.3.1 Establish the Extension Matter-Element Model

Assume that the performance evaluation index system for Industry-University-Research collaborative innovation contains m factors, namely $x_1, x_2, \ldots, x_m$ (in this paper, $m = 10$). Based on these factors and expert or clustering analysis, the Industry-University-Research collaborative innovation performance is quantitatively divided into n levels, which are described as the following matter-element model of qualitative and quantitative evaluation (known as “classical domain matter-element matrix”).

$$R_{oj} = \begin{bmatrix} N_{oj} & x_1 & V_{oj1} \\ & x_2 & V_{oj2} \\ & \vdots & \vdots \\ & x_m & V_{ojm} \end{bmatrix} = \begin{bmatrix} N_{oj} & x_1 & < a_{oj1}, b_{oj1} > \\ & x_2 & < a_{oj2}, b_{oj2} > \\ & \vdots & \vdots \\ & x_m & < a_{ojm}, b_{ojm} > \end{bmatrix}, \tag{75.1}$$

where N_{oj} represents the Industry-University-Research collaborative innovation performance at the jth level; R_{oj} represents the matter-element model for the Industry-University-Research collaborative innovation performance at Level j; $V_{ojk} =< a_{ojk}, b_{ojk} >$ represents the range of the value of x_k, which represents the kth influencing factor of the Industry-University-Research collaborative innovation performance at level $j = 1, 2, \ldots, n$; $k = 1, 2, \ldots, m$.

The range of values of index forms the following matter-element model (known as “joint domain material matrix”):

$$R = \begin{bmatrix} N_p & x_1 & V_{p1} \\ & x_2 & V_{p2} \\ & \vdots & \vdots \\ & x_m & V_{pm} \end{bmatrix} = \begin{bmatrix} N_p & x_1 & < a_{p1}, \ b_{p1} > \\ & x_2 & < a_{p2}, \ b_{p2} > \\ & \vdots & \vdots \\ & x_m & < a_{pm}, \ b_{pm} > \end{bmatrix}, \tag{75.2}$$

where R_p represents the joint domain of the matter-element model for Industry-University-Research collaborative innovation performance evaluation; N_p represents all the levels of the Industry-University-Research collaborative innovation performance; $V_{pk} =< a_{pk}, \ b_{pk} >$ denotes the allowed value range of factor index $V_{pk} =< a_{pk}, \ b_{pk} >, x_k, V_{ojk} \subset V_{pk}, j = 1, 2, \ldots, n; k = 1, 2, \ldots, m.$

75.3.2 Establish Matter-Element Matrix of the Performance of IURCI Being Evaluated

The Industry-University-Research collaborative innovation performance is evaluated based on these factor index in Table 75.1. The acquired data of evaluation or analysis result forms the following matter-element matrix:

$$R = \begin{bmatrix} N & x_1 & v_1 \\ & x_2 & v_2 \\ & \vdots & \vdots \\ & x_m & v_m \end{bmatrix}. \tag{75.3}$$

The N represents the Industry-University-Research collaborative innovation performance to be evaluated; v_k represents the evaluation value of x_k, the kth factor in the Industry-University-Research collaborative innovation performance ($k = 1, 2, \ldots, m$).

75.4 The Extension Evaluation Method for the Performance Evaluation of IURCI

After establishing the matter-element model, the next question is how to specifically evaluate the performance level of Industry-University-Research collaborative innovation. In this regard, it is necessary to calculate the "approach degree" between the matter-element matrix (Eq. 75.3) and the classical domain matter-element matrix (Eq. 75.1) for the Industry-University-Research collaborative innovation performance to be evaluated. In this paper, the dependent function of extension set is used to calculate the approach degree [4].

75.4.1 Definition of Approach Degree

Let

$$p(v_{k,}V_{ojk}) = \left| v_k - \frac{a_{ojk} + b_{ojk}}{2} \right| - \frac{1}{2}(b_{ojk} - a_{ojk}) \;\; k = 1, 2, \ldots, m; \;\; j = 1, 2, \ldots, n,$$
$$p(v_{k,}V_{pk}) = \left| v_k - \frac{a_{pk} + b_{pk}}{2} \right| - \frac{1}{2}(b_{pk} - a_{pk}) \;\; k = 1, 2, \ldots, m; \;\; j = 1, 2, \ldots, n, \tag{75.4}$$

which denote the "approach degree" between point v_k with interval V_{ojk} and V_{pk} respectively. For example, $p(v_k, V_{pk}) \geq 0$ indicates that v_k is not in interval V_{pk}; $p(v_k, V_{pk}) \leq 0$ indicates that v_k is within interval V_{pk}. Meanwhile, different negative values indicate different positions of v_k in interval V_{pk}.

75.4.2 Establishment of Correlation

Let

$$K_j(v_k) = \frac{p(v_k, V_{ojk})}{p(v_k, V_{pk}) - p(v_k, V_{ojk})} \qquad j = 1, 2, \ldots, n; \;\; k = 1, 2, \ldots, m, \tag{75.5}$$

which denotes the correlation between the kth factor index x_k of the Industry-University-Research collaborative innovation performance and level j, $-\infty < K_j(v_k) < +\infty$. $K_j(v_k) \geq 0$ indicates that v_k belongs to V_{ojk}, $K_{j(v_k)} \leq 0$, indicates v_k does not belong to V_{ojk}, $K_j(v_k)$ smaller, the smaller $K_{j(v_k)}$, the farther v_k is away from the range V_{ojk}.

75.4.3 Determination of the Level of IURCI Performance

According to the above formula, the correlation matrix between the evaluation indexes and the performance levels of the Industry-University-Research collaborative innovation performance can be calculated as follows.

$$K = [K_j(v_k)_{m \times n}]. \tag{75.6}$$

Through the aforementioned correlation matrix to calculate:

$$\max_{1 \leq j \leq n} K_j(v_k) = K_{io}(v_k) = K^*(v_k) \qquad k = 1, 2, \ldots, m, \tag{75.7}$$

where $K_{i_0}(v_k)$ indicates that the kth evaluation index x_k of the Industry-University-Research collaborative innovation performance is located at level i_o. The level of Industry-University-Research collaborative innovation performance can be calculated by $K_{i_0}(v_k)$.

If $w_k(\sum_{k=1}^{m} w_k = 1)$ is the weight coefficient of index x_k, the correlation between the Industry-University-Research collaborative innovation performance to be evaluated and the jth level of performance is:

$$K_j(R) = \sum_{k=1}^{m} w_k K_j(v_k). \tag{75.8}$$

The formula above has comprehensively considered the different effects of different indexes in the performance evaluation index system. Therefore, it has a strong level of scientificity and feasibility.

Calculate

$$K_{j_0}(R) = \max_{1 \le j \le n} K_j(R). \tag{75.9}$$

Then the Industry-University-Research collaborative innovation performance to be evaluated belongs to level j_0.

75.5 Empirical Study

In recent years, Sichuan province has accelerated the cultivation and development of strategic emerging industries, upgraded the pattern of economic development and optimized the industrial structure, in order to improve regional competitiveness. The next section will evaluate the Industry-University-Research collaborative innovation performance of Sichuan provincial strategic emerging industries by the extension matter-element model.

The Industry-University-Research collaborative innovation performance is classified into five levels = one, two, three, four, five ≡ unqualified, qualified, medium, good, excellent. When the index of the Industry-University-Research collaborative innovation performance x_k (Table 75.1) is at level one, level two, level three, level four and level five respectively, correspondingly, its evaluation value is equal to v_1, v_2, v_3, v_4 and v_5,where $v_1 \in (0, 1]$, $v_2 \in (1, 2]$, $v_3 \in (2, 3]$, $v_4 \in (3, 4]$ and $v_5 \in [4, 5]$.

75.5.1 Determine the Matter-Element Matrix

According to the value ranges of the Industry-University-Research collaborative innovation performance index ($k = 1, 2, \ldots, 10$), the classical domain matter-element matrix of the Industry-University-Research collaborative innovation performance can be obtained as follows:

$$R_{01}=\begin{bmatrix} N_{01} & x_1 & <0,1> \\ & x_2 & <0,1> \\ & \vdots & \vdots \\ & x_{10} & <0,1> \end{bmatrix}, R_{02}=\begin{bmatrix} N_{02} & x_1 & <1,2> \\ & x_2 & <1,2> \\ & \vdots & \vdots \\ & x_{10} & <1,2> \end{bmatrix}, R_{03}=\begin{bmatrix} N_{03} & x_1 & <2,3> \\ & x_2 & <2,3> \\ & \vdots & \vdots \\ & x_{10} & <2,3> \end{bmatrix},$$
$$R_{04}=\begin{bmatrix} N_{04} & x_1 & <3,4> \\ & x_2 & <3,4> \\ & \vdots & \vdots \\ & x_{10} & <3,4> \end{bmatrix}, R_{05}=\begin{bmatrix} N_{05} & x_1 & <4,5> \\ & x_2 & <4,5> \\ & \vdots & \vdots \\ & x_{10} & <4,5> \end{bmatrix}. \quad (75.10)$$

According to the allowed range of values for the various Industry-University-Research collaborative innovation performance indexes, the domain matter-element matrix can be obtained as follows:

$$R_p=\begin{bmatrix} N_p & x_1 & <0,5> \\ & x_2 & <0,5> \\ & \vdots & \vdots \\ & x_{10} & <0,5> \end{bmatrix}. \quad (75.11)$$

75.5.2 Determination of Matter-Element Matrix for Collaborative Innovation Performance

The evaluation values of the Industry-University-Research collaborative innovation performance indexes are determined by the following method:

Firstly, construct the team of evaluators. The team of evaluators is composed of 11 members, including 7 experts from related fields and 4 government officials. Then, the evaluators are requested to rate the various indexes $x_k (k = 1, 2, \ldots, 11)$ on the basis of the following criteria.

If an evaluator evaluates index x_k as "unqualified", the value of this index will be $u_1 (u_1 \in [0, 1])$; if the index x_k is evaluated as"qualified", the value of this index will be $u_2 (u_2 \in (1, 2])$; by that analogy, if the index x_k is evaluated as"excellent", the value of this index will be $u_5 (u_5 \in (4, 5])$.

If the ith evaluator evaluates index x_k as u_i, the evaluation value of index x_k will be $v_k = \frac{1}{11} \sum_{i=1}^{11} u_i$.

According to the method above, the set of indexes $x_k (k = 1, 2, \ldots, 10)$ need to be evaluated by all the evaluators. Thus, the matter-element matrix of the Industry-University-Research collaborative innovation performance can be obtained as follows

$$R = \begin{bmatrix} N & x_1 & 3.92 \\ & x_2 & 4.05 \\ & x_3 & 3.06 \\ & \vdots & \vdots \\ & x_9 & 3.91 \\ & x_{10} & 3.52 \end{bmatrix}. \quad (75.12)$$

75.6 Evaluation of the IURCI of Sichuan Province

(1) Calculation of correlation matrix

The correlation matrix $K = \left[K_j(v_k)_{10\times 5}\right]$ between the various indexes and levels of performance for the Industry-University-Research collaborative innovation of Sichuan provincial strategic emerging industries can be calculated as follows:

$$K = \left[K_j(v_k)_{10\times 5}\right] = \begin{bmatrix} -0.3450 & -0.0508 & 0.0565 & -0.2957 & -0.4718 \\ -0.3660 & -0.1337 & 0.1825 & -0.2117 & -0.4088 \\ -0.4040 & -0.2053 & 0.1920 & -0.1387 & -0.3673 \\ -0.1136 & 0.1470 & -0.4265 & -0.6177 & -0.7133 \\ -0.3122 & 0.1017 & -0.0845 & -0.3897 & -0.5423 \\ -0.3805 & -0.1740 & 0.2390 & -0.1617 & -0.3736 \\ -0.4463 & -0.2617 & 0.1075 & -0.0885 & -0.3542 \\ -0.3458 & -0.0540 & 0.0605 & -0.2930 & -0.4698 \\ -0.2903 & 0.2225 & -0.1540 & -0.4360 & -0.5770 \\ -0.3667 & -0.1364 & 0.1875 & -0.2083 & -0.4063 \end{bmatrix}. \quad (75.13)$$

(2) Calculating the correlation

According to expert survey and the AHP method, the weight coefficient $w_k (k = 1, 2, \ldots, 10)$ of the various indexes of the Industry-University-Research collaborative innovation performance evaluation $x_k (k = 1, 2, \ldots, 10)$ can be determined as follows: $w_k = (0.0490, 0.0889, 0.1570, 0.0666, 0.2469, 0.1074, 0.0948, 0.1115, 0.0302, 0.0478)$.

Then, the correlation between the Industry-University-Research collaborative innovation performance of strategic emerging industries in Sichuan province and the performance on jth level can be calculated as follows:

$$K_j(R) = \sum_{k=1}^{11} w_k K_j(v_k), \quad (j = 1, 2, 3, 4, 5). \quad (75.14)$$

Substitute the weight coefficients and the correlation matrix of the Industry-University-Research collaborative innovation performance evaluation into the equation above, and the following results can be obtained.

$$K_j(R) = \sum_{k=1}^{11} w_k K_j(v_k) = (-0.3456, -0.0610, 0.0468, -0.2740, -0.4615). \tag{75.15}$$

That is:

$$\begin{aligned} &K_1(R) = -0.3456,\ K_2(R) = -0.0610,\ K_3(R) = 0.0468 \\ &K_4(R) = -0.2740,\ K_5(R) = -0.4615. \end{aligned} \tag{75.16}$$

Then

$$K_{j_0}(R) = \max_{1 \le j \le 5} K_j(R) = K_4(R) = 0.0468. \tag{75.17}$$

Therefore, the Industry-University-Research collaborative innovation performance of Sichuan provincial strategic emerging industries belongs to level three. That is, the collaborative innovation performance is qualified.

Similarly, the input performance, output performance and innovation environment performance of the Industry-University-Research collaborative innovation of Sichuan provincial strategic emerging industries can be calculated as well according to the method above (the calculation process is omitted due to space constraint). The results show that the input performance, output performance and innovation environment performance are medium, qualified and qualified respectively.

75.6.1 Conclusions and Recommendations

Further analysis shows that the problems of the Industry-University-Research collaborative innovation of Sichuan provincial strategic emerging industries are mainly reflected in the following three aspects: transformation of entrepreneurial achievements, diffusion of entrepreneurial achievements and financing channels. In order to improve the overall performance of Industry-University-Research collaborative innovation, the following recommendations are put forward:

Firstly, optimize the legal and political system of technology conversion. The patent law and contract law need to be further optimized, and the efforts in protection of intellectual property rights need to be intensified. The government should encourage colleges and universities, research institutions and enterprises to convert technological achievements into productivity. It is also necessary to encourage the development of intermediary agencies and to strengthen the construction of information service and trading platform in order to stimulate the market of technology conversion.

Secondly, create an effective platform of Industry-University-Research collaborative innovation. An effective Industry-University-Research collaborative innovation platform can not only promote interactions and communications among colleges and universities, research institutions and enterprises, but also improve the practicability of scientific research achievements, and thereby bring more new products into the market. In terms of talent cultivation, the government should support the collaboration among colleges, universities and enterprises. In terms of project development, the government should encourage technical cooperation between colleges and universities, research institutions and enterprises in order to develop products and technologies that comply with the market need.

Thirdly, broaden financing channels. Sichuan province needs to set up the funds of industrial technology research and development at an appropriate time. The government should be committed to support the development of key and innovative projects in high and new technology industries and to promote the integration of industrial chain and the development of characteristic industrial parks. At the same time, the local government needs to activate the linkage between policies for high and new technology industries and financial policies. Specifically, a possible measure is to support high and new technology enterprises to financing directly by listing, or issuing corporate bonds and short-term financing securities, to promote their development.

75.7 Conclusion

Based on the extenics matter-element and extension set theory, in this paper, the extension matter-element model and the extension evaluation method for the performance evaluation of Industry-University-Research collaborative innovation are constructed. The research findings suggest that: (1) the established method can comprehensively consider the state of various factors that affect the industry-university-research collaborative innovation performance and can evaluate the level of performance objectively and accurately; (2) the established matter-element model is efficient, practical and simple to use, not requiring a large number of state evaluation samples; meanwhile, the evaluation results are intuitive; (3) this method provides a new approach for the performance evaluation of Industry-University-Research collaborative innovation, and has a good application prospect.

Acknowledgments This research was supported by the Soft Science Research Plan Project from 2015 to 2016, Sichuan, China, No. 2015ZR0016.

References

1. Cao J (2010) The performance evaluation research on industry-university-research collaborative technological innovation. Sci Tech Prog Policy 4:114–118
2. Ding J (2010) Study on science research evaluation index system with optimization method-in technological innovation competitiveness of china universities evaluation case study. Sci Res Manag 7:111–118

3. Fan B (2002) Research on screening method of urban technology innovation evaluation system. Sci Tech Res 12:663–668
4. Li J, Ji C et al (2008) Matter-element model of integrated risk assessment for flood control systems. Int J Risk Assess Manag 8:342–352
5. Liu R (2013) Research on the method of construction of the evaluation system. Electron Des Eng 1:34–36
6. Tyler K, Patton M et al (2007) Key drivers of university-industry relationships: the role of organisational compatibility and personal experience. J Serv Mark 21(5):370–382
7. Wang B (2011) The innovation level evaluation of high and new technology industry based on the entropy value method. Ind Econ Rev 3:5–11
8. Wang Y, Lu L (2007) Knowledge transfer through effective universityindustry interactions: empirical experiences from China. J Tech Manag China 2:119–133
9. Wen C (1987) Matter element analysis. Guangzhou Higher Education Press, Guangzhou
10. Yan H (2009) Construction of evaluation index system and research on evaluation method of industry-university-research collaborative innovation. Sci Technol Prog Policy 5:125–128

Chapter 76
Simulation of Dynamical Enterprises Process with Application of the Modification Fuzzy Net Petri

Mahommed Aydin Ahmedov, Valeh Azad Mustafayev, Gafar Nariman Atayev and Shafahat Rahim Rahimov

Abstract Simulation of dynamic interacting processes which describe the functioning of complicated objects in conditions of indeterminacy has been considered. The models of dynamic processes are presented in a form of fuzzy net Petri type V_f. On the example of flexible manufacturing module of mechanical processing it was shown that the accepted rules of activate transitions describe completely the process of functioning of fuzzy net Petri type V_f.

Keywords Production model · Fuzzy petri net · Flexible manufacture module

76.1 Introduction

One of the basic problems of the management theory is investigation and simulation of process which execute by different limiting conditions [4, 5, 8]. The basic criterions of solution difficulty of this problem are being complex structural and functional connections between the system elements, but not digital and linguistic parameter presentation of this connections, asynchrony of process, independent. For removal of this difficulty at present new methods, formalizations and simulation apparatus creation are demanding.

In this connection, for efficiency solution of this problem it is necessary to develop system complex methods which are based by new mathematical models, simulation apparatus, algorithms and progressive computer technology [3, 10, 11]. The base of this problem is creation net Petri and its different extension of formalization. Thus, application of fuzzy net Petri and its different modifications for simulation

M.A. Ahmedov (✉) · S.R. Rahimov
Department of Information Technology and Programming of Sumgait State University, Sumqayit, Azerbaijan
e-mail: shafahat_61@mail.ru

V.A. Mustafayev · G.N. Atayev
Department of Computer Sciences of Sumgait State University, Sumqayit, Azerbaijan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_76

dynamical connection which works in the conditions of fuzzy area is scientific-technical problem.

76.2 Presentation of Rules of Fuzzy Productions as the Modified Fuzzy Net Petri

The fuzzy models based on the rules of calculation with fuzzy nets are the evident and effective means of presentation of interactive dynamic processes representing data and knowledge as ≪ if …, then … ≫. In a general view to the rules fuzzy products is the expression [2, 7]:

$$Q;\, X;\, A \Rightarrow B,\, S,\, F,\, Y, \tag{76.1}$$

where i the name of fuzzy products: Q is characteristic of application area of fuzzy production; X is term of applicability of kernel of fuzzy production; $A \Rightarrow B$ kernel of fuzzy production where A a condition of kernel or antecedent; B is a conclusion of kernel or consequent; $\Rightarrow$ a sign of logical secession or following; S a method of determination of quantitative value of degree of truth of conclusion of kernel; F factor of definiteness or confidence of fuzzy production; Y are post-terms of production.

At the decision of tasks of fuzzy simulation of dynamic interactive processes and estimation of the approach reasoning, the modified fuzzy net Petri (NP) are used. Fuzzy NP of type of V_f is determined as [6]:

$$V_f = (P, T, I, O, \mu_0)\,, \tag{76.2}$$

where $P = \{p_1, p_2, \ldots, p_n\}$ is a finale fuzzy set of position; $T = \{t_1, t_2, \ldots, t_m\}$ is a finale fuzzy set of transactions; $I : P \times T \to N_0$ is a internal function of transactions; $O : T \times P \to N_0$ is a output function of transactions; μ_0 is the matrix of initial marking, where its size is $[n \times (d + 1)]$. Every element of μ_{ij}^0 of that matrix is value of the function of suitable of $(j - 1)$ marker number in position p_i of fuzzy NP of type V_f on a moment of activity beginning. By definition of the function of suitable of the matrix elements with beginning marking must execute the following condition:

$$\mu_{ij}^0 = [0, 1], [i \in (1, 2, \ldots, n)\,,\, j \in J]. \tag{76.3}$$

$N_0 = \{0, 1, 2, 3, \ldots\}$ is the set of natural numbers and zero. The set J is defined as $J = \{1, \ldots, d, d + 1\} \subset N_0$, as some finale subset n_0 including $d + 1$ of first natural numbers.

Advantage of modified fuzzy NP is their using for evident presentation of rules of fuzzy productions and implementation on their basis of conclusion of fuzzy conclusions. The following interpretation of positions and transitions of modified fuzzy NP is used in this case. Rule of fuzzy productions of kind: ≪ i : if $A \ldots$ then B ≫

appears as some transition $t_j \in T$, by that condition. Entrance position $p_j \in P$ is corresponds to this rule, and conclusion is an output position of this transition.

If the condition of rule of fuzzy production consists of a few under terms connected by the operation of fuzzy logical conjunction $A = A_1$ and A_2 and … and A_n, then all these under terms appear as entrance positions of corresponding transition: $I\,(t_i) = \{A_1, A_2, \ldots, A_n\}\ \ (i \in N)$.

If the conclusion of rule of fuzzy production consists of a few under conclusions, united operations of fuzzy logical conjunction $B = B_1$ and B_2 and … and B_n, then all these under conclusions it appears as output positions of corresponding transition: $O\,(t_i) = \{B_1, B_2, \ldots, B_n\}\ \ (i \in N)$.

If the condition of rule of fuzzy production consists of a few under terms, united operations of fuzzy logical disjunction of $A = A_1$ and A_2 and … and A_n, then all these under terms appear as entrance positions of separate transitions $t_i : I(t_i) = A_i, (i \in N)$.

If the conclusion of rule of fuzzy production consists of a few, under conclusions of the united operations of fuzzy logical disjunction $B = B_1$ and B_2 and … and B_n, then all these under conclusions appear as entrance positions of separate transitions $t_i : O(t_i) = B_i, (i \in N)$.

76.2.1 Functional Algorithm of Fuzzy Net Petri of Type V_f

Solving the practical problems it is convenient to use the matrix representation of the structure of fuzzy PN. The elements of the input matrix f_{ij}, output positions h_{ij} and incidence d_{ij} are determined as follows [9, 11]:

$$f_{ij} = \begin{cases} 1, \text{ if } p_i \in I(t_j), \\ 0, \text{ if } p_i \notin I(t_j). \end{cases} \tag{76.4}$$

$$h_{ij} = \begin{cases} 1, \text{ if } p_i \in O(t_j), \\ 0, \text{ if } p_i \notin O(t_j). \end{cases} \tag{76.5}$$

$$d_{ij} = \begin{cases} -1, \text{ if } p_i \in I(t_j) \text{ and } p_i \notin O(t_j), \\ 1, \quad \text{if } p_i \notin I(t_j) \text{ and } p_i \in O(t_j), \\ 0, \quad \text{if } p_i \notin I(t_j) \text{ and } p_i \notin O(t_j). \end{cases} \tag{76.6}$$

Step 1 Building a matrix of insidente of multi positions: $F = [f_{ij}], (i = \overline{1, n};\ j = \overline{1, m})$; where $P = \{p\}$ and $T = \{t\}$—accordingly great number of finale fuzzy transitions and positions, n and m C the same great number sizes.

Step 2 Building a matrix of insidente of multi transitions: $F = [f_{ij}],\ (i = \overline{1, n};\ j = \overline{1, m})$;

Step 3 Building matrix of initial marking: $\mu = \left[\mu_{ij}\right],\ (i = \overline{1, n};\ j = \overline{1, m})$.

Step 4 Searching settled transition. For every transition t_j, $(j = \overline{1,m})$; the executing condition is checking: From F matrix all internal positions of transition t_j are defined: $p_{i1}, p_{i2}, \ldots, p_{ik}$ where $k = \left|I(t_j)\right|$; if $\forall i_k$ for $\mu_{ik} \geq f_{ij}$ condition is executing, then t_j transition is settled; for sequence of transitions a calculation is defined: $\alpha = 0$.

Step 5 Calculation of accordingly level executing transition t_j: $i = 1$; $j = 1$; $k = 1$; $l = 1$; $q_k = \mu_{11}$ are accepted;
(a) $\mu_{max} = \mu_{i1}$; If $(f_{ij} \neq 0)$ and $(\mu_{\max} < \mu_{i1})$ condition is executing, then $\mu_{\max} = \mu_{i1}$ and $j = j + 1$ is accepted; $j \leq n$ condition is executing, then *Step 5*, it is realized a transition to (a), else $\mu_{max} = \mu_{i1}$ is accepted.

Step 6 $i = i + 1$ is given; if $i \leq n$ condition is executing, then Step 5 a transition to *(a)* is realized, else $q_{i\ell} = \mu_{ij}$; $\ell = \ell + 1$; $\ell = \ell + 1$ is accepted; $\ell \leq n$ condition is executing, then Step 5, a transition to *(a)* is realized.

Step 7 At $\ell = 0$; $q_\ell = \mu_{\max,\ell}$.

Step 8 At $i = 1$; $\ell = 1$; *(a)* $q_\ell = q_{\ell i}$ condition is checking, if this condition is executing, then $q_\ell = q_{\ell i}$ is accepted and $\ell = \ell + 1$ is executed and a transition to (a) is executed.

Step 9 $j = 1$ is accepted. At $f_{i\ell} \neq 0$ condition $\mu_{j1} < \mu_{\ell j}$ is checking, if the condition is executing, then $\mu_{j1} < \underline{\mu_{\ell j}}$ is accepted, else transition t_ℓ is not executing. For this process $(j = \overline{1,n})$ it is proceeds.

Step 10 $i = 1$ is accepted. Condition $h_{\ell i} \neq 0$ is checking. If this condition is executing, then condition $\mu_{ij} > (1 - q\ell)$ is checking. If this condition is executing, then $\mu'_{ij} = 1 - q\ell$ is accepted, else $\mu'_{ij} = \mu_{ij}$.

Step 11 $\alpha = \alpha + 1$ is given and $\beta = 0$ is accepted.
(a) If $\mu_{i\beta} = \mu_{i\alpha}$, $(i = \overline{1,n})$ condition is executing, then a transition from *Step 11* to *(c)* is appeared, else β value is accepted, then its value is rising as: $\beta = \beta + 1$;
(b) If$\beta < \alpha$ if executing, then a transition from Step 11 to *(a)* is executing, else $\mu'_{ij} = \mu_{ij}$ is executing and a transition from Step 5 to *(a)* is appeared;
(c) All μ_{ij} $(i = \overline{1,n}$; $j = \overline{1,m})$ markers and it is building diagram of transitions sequences t_j $(j = \overline{1,m})$.

76.3 Model of Functioning of the Flexible Manufacture Module of Tooling

Let's consider the model of functioning the flexible manufacture module (FMM) of tooling. FMM of tooling includes: the personal entrance store equipment 1; personal entrance store equipment 2; equipment 1 for treatment of the first type of detail; equipment 2 for treatment of the second type of detail; personal output store equipment 1; personal output store equipment 2; an industrial robot (IR) for loading and unloading equipment 1 and equipment 2 accordingly.

Connection of the module with previous and subsequent the modules takes place accordingly by means of foregoing stores. On the module two types of details are processed. The module works as follows: details act on the personal entrance stores and expect treatment; at presence of details of entrance stores of IR an equipment carries out loading 1, after equipment 2, after treatment of details there is their unloading and cycle recurs.

In the imitation model [1] made by means of fuzzy PN status of FMM tooling are described by next positions: p_1: IR is executed by the operations of loading-unloading equipment 1 and equipment 2; p_2: the personal entrance store of equipment 1; p_3: the personal entrance store of equipment 2; p_4: completed IR loading equipment 1 and equipment 1 in the state implementation of operation; p_5: completed IR loading equipment 2 and equipment 2 in the state implementation of operation; p_6: an equipment 1 completed operations and in a state of unloading; p_7: an equipment 2 completed operations and in a state of unloading; p_8: the personal output store of equipment 1; p_9: the personal output store of equipment 2; $p_1 0$: an equipment 1 it is not unloaded and will not be loaded; $p_1 1$: an equipment 2 it is not unloaded and will not be loaded.

Possible events in the module of tooling are described by transitions: t_1 IR is executed by the operations of loading equipment 1; t_2 IR is executed by the operations of loading equipment 2; t_3: an equipment 1 execute an operation above a detail; t_4: equipment 2 executes an operation above a detail; t_5: IR is off-loaded equipment 1; t_6: IR is off-loaded equipment 2.

The function of incident of great numbers of positions is represented by means of the matrix F [6, 11]:

$$F = \begin{array}{c} \\ p_1 \\ p_2 \\ p_3 \\ p_4 \\ p_5 \\ p_6 \\ p_7 \\ p_8 \\ p_9 \\ p_{10} \\ p_{11} \end{array} \begin{array}{c} \begin{array}{cccccc} t_1 & t_2 & t_3 & t_4 & t_5 & t_6 \end{array} \\ \begin{pmatrix} 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \end{pmatrix} \end{array}.$$

The function of incident of great numbers of transitions is represented by means of the matrix of H [6, 11]:

$$H = \begin{array}{c} \\ t_1 \\ t_2 \\ t_3 \\ t_4 \\ t_5 \\ t_6 \end{array} \begin{array}{c} \begin{array}{ccccccccccc} p_1 & p_2 & p_3 & p_4 & p_5 & p_6 & p_7 & p_8 & p_9 & p_{10} & p_{11} \end{array} \\ \begin{pmatrix} 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \end{pmatrix} \end{array}.$$

The incidence matrix of entrance and output function is represented by means of the matrix D [6, 11]:

$$D = \begin{array}{c} \\ t_1 \\ t_2 \\ t_3 \\ t_4 \\ t_5 \\ t_6 \end{array} \begin{array}{c} \begin{array}{ccccccccccc} p_1 & p_2 & p_3 & p_4 & p_5 & p_6 & p_7 & p_8 & p_9 & p_{10} & p_{11} \end{array} \\ \begin{pmatrix} 0 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & -1 \\ 0 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & -1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & -1 & 0 & 1 & 0 & 1 \end{pmatrix} \end{array}.$$

Initial marked μ_0 is presented as matrix:

$$\mu_0 = \begin{bmatrix} 0.20 & 0.30 & 0.00 & 0.35 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.15 & 0.00 \\ 0.35 & 0.00 & 0.20 & 0.00 & 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.20 \\ 0.00 & 0.00 & 0.40 & 0.00 & 0.00 & 0.30 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.10 & 0.00 & 0.00 & 0.20 & 0.40 & 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.30 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.20 \end{bmatrix}.$$

On the basis of the developed algorithm, structure of fuzzy net Petry of type V_f is formed. In a result of computer experiment activation of transitions $\sigma = (t_1\, t_2\, t_3\, t_4\, t_5\, t_6)$ with initial marking μ_0 is got.

The marked getting at activate transition of t_1:

$$\mu_1 = \begin{bmatrix} 0.20 & 0.30 & 0.00 & 0.35 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.15 & 0.00 \\ 0.00 & 0.10 & 0.10 & 0.40 & 0.10 & 0.00 & 0.10 & 0.00 & 0.00 & 0.00 & 0.20 \\ 0.00 & 0.00 & 0.60 & 0.00 & 0.00 & 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.10 & 0.00 & 0.00 & 0.20 & 0.40 & 0.30 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.30 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.10 & 0.00 & 0.30 & 0.00 & 0.20 \end{bmatrix}.$$

The marked getting at activate transition of t_3:

$$\mu_2 = \begin{bmatrix} 0.30 & 0.25 & 0.00 & 0.20 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.15 & 0.00 \\ 0.35 & 0.00 & 0.20 & 0.00 & 0.10 & 0.00 & 0.10 & 0.00 & 0.00 & 0.00 & 0.15 \\ 0.00 & 0.00 & 0.30 & 0.00 & 0.00 & 0.70 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.10 & 0.00 & 0.00 & 0.20 & 0.40 & 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.60 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.20 & 0.00 & 0.20 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.20 \end{bmatrix}.$$

The marked getting at activate transition of t_5:

$$\mu_3 = \begin{bmatrix} 0.20 & 0.20 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.50 & 0.00 \\ 0.30 & 0.00 & 0.20 & 0.00 & 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.20 \\ 0.00 & 0.00 & 0.60 & 0.00 & 0.00 & 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.10 & 0.00 & 0.00 & 0.20 & 0.40 & 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.30 & 0.00 \\ 0.20 & 0.20 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.20 \end{bmatrix}.$$

The marked getting at activate transition of t_2:

$$\mu_4 = \begin{bmatrix} 0.20 & 0.30 & 0.00 & 0.30 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.15 & 0.00 \\ 0.30 & 0.00 & 0.30 & 0.00 & 0.10 & 0.00 & 0.00 & 0.20 & 0.00 & 0.00 & 0.10 \\ 0.00 & 0.00 & 0.30 & 0.00 & 0.00 & 0.70 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.10 & 0.00 & 0.00 & 0.20 & 0.40 & 0.10 & 0.00 & 0.00 & 0.00 & 0.10 & 0.00 \\ 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.20 & 0.00 & 0.70 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.20 \end{bmatrix}.$$

The marked getting at activate transition of t_4:

$$\mu_5 = \begin{bmatrix} 0.20 & 0.30 & 0.00 & 0.30 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.15 & 0.00 \\ 0.40 & 0.00 & 0.20 & 0.00 & 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 \\ 0.00 & 0.00 & 0.40 & 0.00 & 0.00 & 0.30 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.10 & 0.00 & 0.00 & 0.20 & 0.40 & 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.80 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.10 & 0.00 & 0.10 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.20 \end{bmatrix}.$$

The marked getting at activate transition of t_6:

$$\mu_6 = \begin{bmatrix} 0.20 & 0.30 & 0.00 & 0.30 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.10 & 0.00 \\ 0.20 & 0.00 & 0.20 & 0.00 & 0.20 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.20 \\ 0.00 & 0.00 & 0.40 & 0.00 & 0.00 & 0.30 & 0.00 & 0.20 & 0.00 & 0.10 & 0.00 \\ 0.30 & 0.00 & 0.00 & 0.20 & 0.40 & 0.10 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.30 & 0.00 \\ 0.40 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.30 & 0.00 & 0.20 \end{bmatrix}.$$

76.4 Conclusion

The developed algorithm of fuzzy net Petri of type V_f working provides efficiency transformation of external data to internal format at simulation area; effective presentation of the structure; dynamical status of the model; space of getting status and sequence of activation of transactions as complex of vectors and matrix; simples and high speed of simulation process.

The program is worked out in the system DELPHI 7.0 by means of the algorithm. The resources of progressive computers allow to solve the problems with matrix of great sizes that provide the demands to simulation of the real difficult objects worked at condition of non determination.

References

1. Akhmedov MA, Mustafayev VA (2010) Development of fuzzy model for investigation functioning active elements of the flexible manufacture model. Appl Fuzzy Syst Soft Comput, pp 315–320
2. Borpsov VV, Kruglov VV, Fedulov AS (2012) Fuzzy models and networks. Hotline-Telecom, Moscow (in Russian)
3. Ding Z, Zhou Y, Zhou M (2015) A polynomial algorithm to performance analysis of concurrent systems via petri nets and ordinary differential equations. IEEE Trans Autom Sci Eng 12(1):295–308
4. Golikov BK, Matusov KN, Sisoyev VV (2002) Petri nets in a situational management and imitation design of the discrete technological systems. Radio Engineering (in Russian)
5. Iordache MV, Antsaklis PJ (2006) Decentralized supervision of petri nets. A petri net structural approach, supervisory control of concurrent systems, pp 93–123
6. Leskin A, Maltsev P, Spiridonov A (1989) Petri networks in modeling and control. Leningrad, Nauka (in Russian)
7. Osuga S (1986) Processing expertise. Wiley, New York
8. Pedrycz W (1996) Fuzzy models: methodology, design, applications and challenges. In: Fuzzy Modelling, Springer, Heidelberg, pp 3–22
9. Peterson J (1984) The theory of petri networks and systems modeling. Prentice Hall PTR, Moscow (in Russian)
10. Vazquez CR, Silva M (2015) Stochastic hybrid approximations of markovian petri nets. IEEE Trans Syst Man Cybern Syst 45(9):1231–1244
11. Yegorov A, Shaykin AN (2002) Logical modeling under uncertainty based on fuzzy interval petri network. Theory Control Syst 2:234–239 (in Russian)

Chapter 77
Tourism Economic Effect Divergence Analysis–Panel Data Analysis of Hunan Province

Jie Chen, Xiaowen Jie and Song Han

Abstract This paper aims to analyze the tourism economic benefit divergence in Hunan Province. Data from 2005 to 2013 are used and 4 indexes are used to form a panel data: tourism total income, domestic tourism income, international tourism income and regional gross domestic product. Co-integration and granger causality are used to analyze the relationship between regional tourism income and economic development. Research shows Human province is not tourism led growth economy. Co-integration test and granger causality test show that synergistic effort exists between regional tourism income and economic growth. But it also indicates that bidirectional granger causality exists more between domestic tourism income and economic development than between international tourism income and economic development.

Keywords Tourism economy effect · Panel data · Divergence · Hunan

77.1 Introduction

In recent years, tourism has developed greatly in China, and tourism economy effect continuously magnified. Tourism income has been taking up a bigger proportion in GDP. According to Hunan province report in 2014, tourism income was 300.9 billion, which accounted for 11.3 % of GDP. Domestic tourism income was 300.1 billion and inbound tourism income was 0.8 billion. It is predicated tourism will take up a bigger portion in GDP.

Hunan province has abundant tourism resources. There are over 20 thousand discovered scenic spot vary from natural heritage, historic humanity, mountain landscape and cultural landscape. World Natural Heritage like Wulingyuan Scenic Area (Zhangjiajie, Suoxiyu and Tianzishan, etc.); Historic humanity scenic spot

J. Chen (✉) · X. Jie · S. Han
Business School, SiChuan University, Tourism Management, Chengdu 610065, People's Republic of China
e-mail: chenjie33403@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_77

like Yueyang Tower, Dongting Lake, Juzizhou, The Peach Garden and Fenghuang Ancient City; Mountain Landscape like Hengshan Mountain and Langshan Mountain; Cultural landscape like Yuelu Academy, Han Dynasty Tomb and Emperor Yandi Mausoleum. These tourism destinations are in good quality. Varies tourism resources lead to different tourism economy effect in Hunan.

This paper aims to do deep research on tourism economy effect divergence to reveal the tourism development discipline in Hunan province, thus providing suggestions for Hunan province tourism development. Statistics of 14 municipalities in Hunan province from Yearbook of Hunan Province are used. Data like GDP and tourism income are given in details. Unit root test, co-integration test and granger causality test are utilized in panel data analysis.

This paper will be organized in five parts: part one is introduction which mainly aims to introduce the purpose of this paper. Part two is the literature review of tourism economic effect. Part three is data resources and manipulation. Part four is data analysis and part five is conclusion.

77.2 Previous Researches on Tourism Economic Effect

Tourism economic effect means the impact or influence tourism makes on tourism destination economy. The impact mainly includes income effect, foreign exchange effect, employment effect and industrial correlation effect, etc1. Researchers have done a lot of work on tourism economic effect, and most of them concentrate on exploring the relationship between tourism and economy growth.

Researchers abroad mainly concentrate on whether tourism development and economic growth have mutual boost, under what condition they could influence each other and whether different countries show any differences. Archer [1] contended that the multiplier effect of tourism to regional economy varies tremendously with different tourism consumption level. Balaguer [2] proposed "tourism led growth hypothesis" first. Data from 1975–1997 in Spanish is used. Co-integration test and Granger causality test are used to verify the hypothesis. In contrary, Chiok [10] used Korean tourism and economy statistics to refute the "tourism led growth hypothesis", and contended the hypothesis doesn't fit for Korea. Lee [6] used heterogeneous panel data co-integration to compare the long term economy effect of tourism to Organization for Economic Co-operation and Development (OECD) and non-OECD. It shows the unidirectional improvement between tourism and economy development in OECD and bidirectional improvement in non-OECD, in which Asia has week correlation between tourism and economy development. Kim [5] analyzed tourism and economy development using Taiwan statistics. Co-integration test and Granger causality test reveal that a long term equilibrium relationship and bidirectional causality relationship exist, which improve tourism and economy boost each other in Taiwan. Ding [4] started from the two hypothesis, i.e. tourism led economy growth (TLEG) and economy led tourism growth (ELTG). Research found with technology, human capital and institution uncontrolled, tourism leads to economy growth. But taking these elements into consideration, tourism has no marginal effect. Can [13] used a new causality test method, proposed by Dumitrescu and Hurlin, to evaluate the impact of tourism to Mediterranean countries economy growth. It concluded that European countries have much higher tourism economic effect. Chor [12] proved that Malaysia is a tourism led economy growth country with tourism being the Granger reason of economy growth. Nikolaos [9] used statistics from 10 European countries from 1995 to 2012 with spillover index method. It shows that when classify a country to "tourism led economy growth" or "economy led tourism growth" has close relation with the environment and economic event at that time.

Researchers at home also explored the relationship of tourism development and economic growth. Li [7] calculated the contribution of tourism to economy growth in Yunnan province. Pang [11] probed into the causality between inbound tourism and regional economy growth. Results show that eastern region inbound tourism Unidirectionally boosts economy increase, but no causality relationship exists between tourism and economy growth in middle and west region. Liu [8] used VAR model and Granger causality test to analyze all province tourism and economy growth in China. Results show a long term equilibrium relationship and bidirectional causality exist between tourism and economy in our country, but impact of economy development to tourism is much greater than tourism to economy growth. Chen and Zhang [3] analyzed tourism impact on economy in Jiangxi province, mainly focusing on income effect, foreign exchange effect, employment effect and industrial correlation effect. Wang [14] contended that domestic tourism and inbound tourism has positive effect on economy growth in China. Zhang [15] found that tourism economy effect divergence exists in Heilongjiang province.

77.3 Data Source and Processing

To analyze the tourism economy effect in Hunan province, this paper uses statistics of 14 municipalities in Hunan province from 2005 to 2013. The 14 municipalities are Changsha, Zhuzhou, Xiangtan, Hengyang, Shaoyang, Yueyang, Changde, Zhangjiajie, Yiyang, Chenzhou, Yongzhou, Huaihua, Loudi and Xiangxi. 4 indexes are chosen: GDP in each municipality, total tourism income in each municipality, domestic tourism income and inbound tourism income, in which domestic tourism income means income produced by Chinese tourists, and inbound tourism income means income produced by tourist abroad.

To standardize all statistics, this paper set year 2005 as the base. Current year constant prices GDP (100 million) was calculated through GDP index. Current year constant prices domestic tourism income (100 million) and inbound tourism income (100 million) were calculated through CPI index. The formula as following:

$$\frac{\text{current year GDP index}}{\text{last year GDP index}} \times \text{last year constant GDP} = \text{current year constant GDP},$$
$$\frac{\text{current year nominal tourism income}}{\text{consumer price index}} = \text{current year actual tourism income}.$$

To eliminate heteroskedasticity, all data are taking logarithm The variables are as follows: LnGDP, LnD, LnI, LnT, which respectively represent GDP of Hunan province, domestic tourism income, inbound tourism income and total tourism income. Panel data analysis software Eviews 6 is used to make scatter diagrams of LnGDP and Lnt, LnGDP and LnD, LnGDP and LnI (Figs. 77.1, 77.2 and 77.3). The figures show apparent positive correlation between economic growth and total tourism income, economic growth and domestic tourism income. Relationship between economic growth and inbound tourism income differs in different regions. Some municipalities show positive correlation while others show instable fluctuation with no apparent linear relationship.

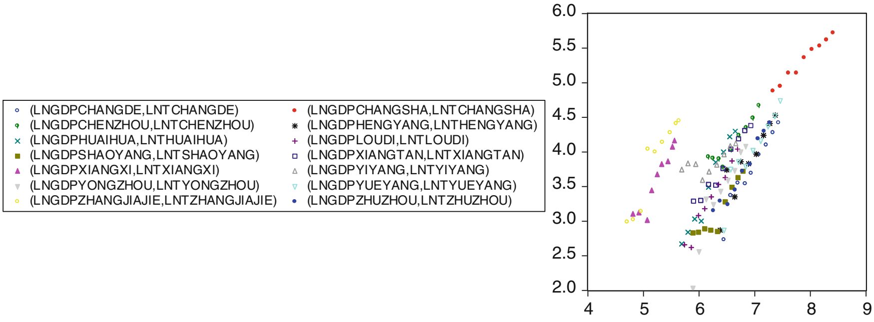


Fig. 77.1 LnGDP and LnT scatter diagram

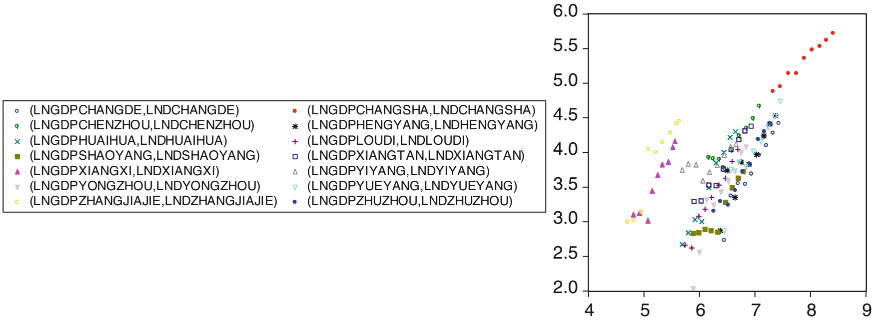


Fig. 77.2 LnGDP and LnD scatter diagram

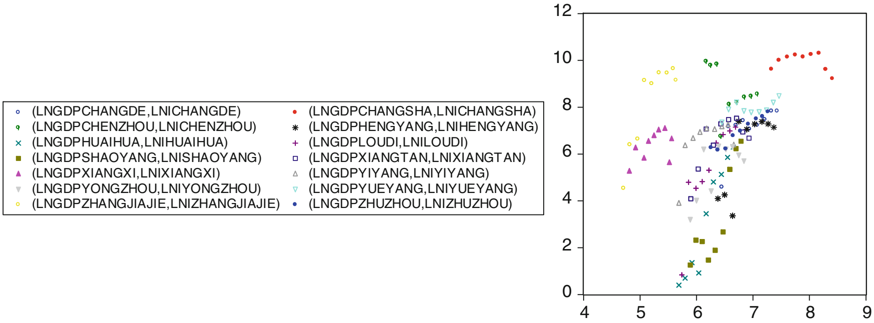


Fig. 77.3 LnGDP and LnI scatter diagram

77.4 Results

77.4.1 Unit Root Test

To assure the robust and reliability of the panel data, unit root test was conducted first. There are 4 unit root test methods which are classified into two categories: same unit root test (LLC) and test with no same unit root (IPSW, ADF and PPF). This paper uses both LLC and Fisher-ADF to test the reliability of the panel data (results shown in Table 77.1).

Unit root test results show that LnGDP is integrated of order 2, LnD is integrated of order 1, and LnI has no unit root. LnGDP original data can only refuse the null hypothesis of LLC "unit root exists", but failed to refuse the null hypothesis of the other three methods. So LnGDP has unit root and original data is not robust. After the first order difference and second order difference unit root tests, it shows second order difference of LnGDP has no unit root. All these data can be used to co-integration test and Granger causality test.

77.4.2 Co-Integration Test

Co-integration test aims to evaluate whether a set of unstable linear series has equilibrium relationship. If certain time series have unit root, it shows variables are not stable and robust and can't be directly used to analyze. But if two unstable series have

Table 77.1 Unit root test of LnGDP, LnD, LnT

Method	LnGDP	LnD	LnI	△△LnGDP	△LnT	△LnD	△LnI
LLC	0	0.0491	0.0000	0	0	0	0
ADF	0.3862	0.9749	0.0043	0.0001	0	0	0

△ represents one order difference, △△ represents two order difference co-integration relationship, then they could be used to conduct regression analysis 5. As far, there are 2 methods to conduct co-integration test: Engle-Granger two-stage method and Johansen test. This paper uses Johansen test to analyze the co-integration of each municipalities in Hunan province. Results of GDP in each municipality and total tourism income co-integration test are shown in Table 77.2. First co-integration between GDP and total tourism income is examined. In Table 77.2, when we take Hunan as a whole research object, null hypothesis "series has no co-integration" because p values are both less than 0.05. It indicates co-integration exists between Hunan GDP and total tourism income. In 14 municipalities, p values of Changsha, Zhuzhou, Hengyang, Yueyang, Changde, Zhangjiajie, Chenzhou, Yongzhou, Loudi and Xiangxi are less than 0.05, which shows that co-integration relationship exists between GDP and total tourism income in these 10 municipalities.

Then co-integration of GDP and domestic tourism income, GDP and inbound tourism income are tested. Co-integration exists between GDP and domestic tourism income in the following 12 municipalities: Changsha, Zhuzhou, Hengyang, Yueyang, Changde, Zhangjiajie, Yiyang, Chenzhou, Yongzhou, Huaihua, Loudi and Xiangxi. Co-integration exists between GDP and inbound tourism income in the following 12 municipalities: Changsha, Zhuzhou, Xiangtan, Hengyang, Shaoyang, Yueyang, Changde, Zhangjiajie, Yongzhou, Huaihua, Loudi and Xiangxi. In general, most places in Hunan show co-integration relationship between economic development and domestic tourism income, economic development and inbound tourism income. (Results are shown in attachment because of the length restriction).

Table 77.2 GDP and total tourism income co-integration test

Place	Trace	P value	Max-eigen	P value
Hunan	215.5	0	185	0
Changsha	23.9	0.002	19.6	0.0065
Zhuzhou	18.6	0.0164	14.5	0.0453
Xiangtan	14.3	0.0749	10.16	0.20
Hengyang	24.8	0.0015	23.09	0.0016
Shaoyang	11.1	0.2028	11.10	0.1493
Yueyang	50.3	0.0000	42.41	0.0000
Changde	38.5	0.0000	37.01	0.0000
Zhangjiajie	23.8	0.0022	17.06	0.0176
Yiyang	14.4	0.0736	12.17	0.1043
Chenzhou	48.2	0.0000	40.42	0.0000
Yongzhou	44.9	0.0000	31.36	0.0000
Huaihua	16.3	0.0376	12.16	0.1049
Loudi	35.2	0.0000	28.74	0.0001
Xiangxi	26.0	0.0009	23.66	0.0013

77.4.3 Granger Causality Test

(1) Granger Causality Test of GDP and Total Tourism Income

Co-integration tests show that co-integration relationship exists between LnGDP and LnT, LnGDP and LnD, LnGDP and LnI. So granger causality test is applicable to these time series to check the direction and causality relationship of economic growth and tourism income. Inbound tourism income has a small proportion in total tourism income, and most places don't show causality relationship between inbound tourism income and economic growth, so causality relationship will not be discussed between them. This paper granger causality test is conducted under simple or quadratic lag, the benchmark of p value is 0.1, which means when p value is less than 0.1 null hypothesis "no granger causality" can be rejected. Results are shown in Table 77.3.

Firstly, taking Hunan as research object, p values of causality test between GDP and total tourism income are less than 0.1, which shows economic growth and total tourism income boost each other at the same time. Tourism resources in Hunan province are abundant in volume but distributed unevenly. Hunan in history is a first industry and second industry dominant province, but in recent years third industry has been paid more and more attention. In 2014 tourism income of Hunan takes up 11 % in GDP and shows a trend of steady growth.

Secondly, p values of causality test in Changde, Chenzhou, Loudi, Hengyang and Xiangxi are less than 0.1, rejecting the null hypothesis of "economic growth is not granger causality of total tourism income". It shows in Changde, Chenzhou, Loudi, Hengyang and Xiangxi, economic growth boosts total tourism income.

But causality relationships in these municipalities are unidirectional which means total tourism income is not granger reason to economic growth. But taking Hunan province as a whole, economic growth and tourism income boost each other. Most areas show economy growth promoted tourism development, but not vice verse. This matches the reality in Hunan province. Because tourism resources in Hunan are in some major areas like Zhangjiajie, Xiangxi, Hengyang, etc. Wulingyuan World Heritage Resort, Fenghuang Ancient City, Hengshan Mountain are in these areas which are the main attractions for visitors. In 2013, tourism income in Zhangjiajie takes up 50 % of GDP, and Xiangxi tourism income was 31 % of GDP. Besides the

Table 77.3 GDP and total tourism income causality test

Null hypothesis	F value	P value	Result
LNGDP is not granger cause of LNTHunan	38.7	0.03	Reject
LNT is not granger cause of LNGDPHunan	9.32	0.03	Reject
LNGDP is not granger cause of LNTChangde	37.36	0.03	Reject
LNGDP is not granger cause of LNTChenzhou	25.34	0.04	Reject
LNGDP is not granger cause of LNTHengyang	14.81	0.06	Reject
LNGDP is not granger cause of LNTLoudi	15.13	0.06	Reject
LNGDP is not granger cause of LNTXiangx	17.17	0.055	Reject

Table 77.4 GDP and domestic tourism income causality test

Null hypothesis	F value	P value	Result
LNGDP is not granger cause of LNDLoudi	20.58	0.0463	Reject
LNGDP is not granger cause of LNDXiangxi	18.21	0.0521	Reject
LND is not granger cause of LNGDPYiyang	12.69	0.073	Reject
LNGDP is not granger cause of LNDYongzhou	51.19	0.0192	Reject
LND is not granger cause of LNGDPHunan	16.88	0.0559	Reject
LNGDP is not granger cause of LNDChangde	25.77	0.0374	Reject

two cities, tourism income contribute little to local economy, and tourism industry needs to be further developed.

(2) Granger Causality Test of Regional GDP and Domestic Tourism Income

Table 77.4 shows Hunan province domestic tourism income is the granger causality to GDP increase which means domestic tourism income boosts economic growth. As the benchmark above, p value below 0.1 can refuse null hypothesis which means causality relationship exists. While in Loudi, Xiangxi, Yongzhou and Changde, economic growth is the granger causality to domestic tourism income increase.

(3) Distribution of Domestic Tourism Income and Inbound Tourism Income in Hunan

To visualize the research results, figures are given to show the income distribution in Hunan province based on the 2013 statistics from China Yearbook.

Figure 77.4 is the distribution of domestic tourism income in Hunan province, which shows domestic tourism income mainly allocate in the following 8 municipalities: Yueyang, Changsha, Hengyang, Chenzhou, Zhangjiajie, Xiangxi, Changde and Zhuzhou which correspond to the tourism resources situation in Hunan province. Yueyang Tower, Hengshan Mountain, Wulingyuan Scenic Area, Chenzhou National Forest, Xiangxi Minority and capital Changsha are the main tourism resources in Hunan and they attract most tourists.

Figure 77.5 is the distribution of inbound tourism income. The deeper the color, the more income this area has. Income mostly distributed in Zhangjiajie, Changsha, Yueyang and Chenzhou. Changsha is the capital of Hunan province and known as entertainment center in China. It attracts tourists from all over the world. Wulingyuan Scenic Area, known as Zhangjiajie, has successfully grabbed the attention of the world in a series of promotion campaigns like wire walking up in the sky and Russian Aerobatic Flight. Recent years Zhangjiajie innovates one of a kind glass skywalk up on the high mountain which becomes a new attraction of this scenic area. Chenzhou is a national tourism city which has very good nature resources like hot spring attracts tourists abroad.

Fig. 77.4 Distribution of domestic tourism income

77.5 Conclusion

This paper uses statistics of Hunan province from year 2005 to 2013 to form panel data series. Unit root test, co-integration test and granger causality are tested to analyze the relationship between GDP and tourism income in Hunan province, the following conclusions can be drawn:

First, domestic and inbound tourism income shows apparent divergence in different areas. Most domestic tourism income is allocated in Yueyang, Changsha, Hengyang, Chenzhou, Zhangjiajie, etc. It indicates these areas show more attraction to domestic tourists and people spend more in these areas. Inbound tourism income mostly allocate in Zhangjiajie, Yueyang, Changsha and Chenzhou because these destinations have more international popularity and attract more foreign tourists. It can be explained from the perspective of tourism resources. Most of Hunan tourism resources distribute in Yueyang, Changsha, Hengyang, Chenzhou in east Hunan, and Zhangjiajie, Changde in north Hunan, and Xiangxi in west Hunan. As industrial base with long history, Xiangtan and Zhuzhou, etc., have less tourism resources and gov-

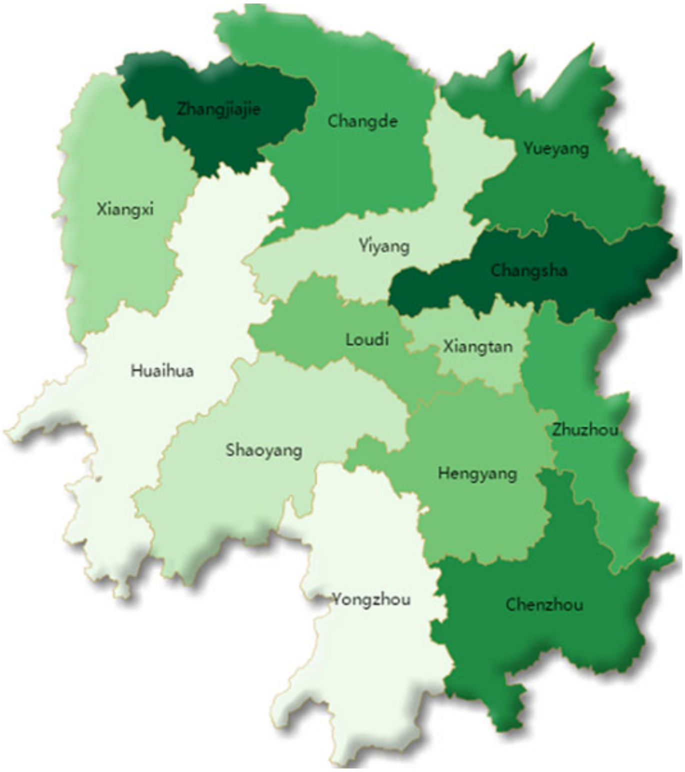


Fig. 77.5 Distribution of inbound tourism income

ernment has paid much more attention on industrial development, they have much less tourism income.

Secondly, economic growth and tourism income co-integration test proves that a long term equilibrium relationship exists between economy and tourism development in Hunan province. It means economy and tourism promote each other. Tourism income is becoming a more and more important part in economy. Co-integration exists between GDP and domestic tourism income in Changsha, Zhuzhou, Hengyang, Yueyang, Changde, Zhangjiajie, Yiyang, Chenzhou, Yongzhou, Huaihua, Loudi and Xiangxi. Co-integration exists between GDP and inbound tourism income in Changsha, Zhuzhou, Xiangtan, Hengyang, Shaoyang, Yueyang, Changde, Zhangjiajie, Huaihua, Loudi and Xiangxi. In general most areas have co-integration relationship between economy growth and tourism development. These areas have abundant natural tourism resources to further develop tourism.

Thirdly, according to the causality test of economic growth and tourism income, economic growth has much greater promotion to tourism income than tourism income to economic growth. Most areas in Hunan province indicate economic growth boost tourism income but few show the vice verse. In western countries tourism or service takes up 40 to 50 % of total economy. It is suggested that tourism in Hunan has great potential. Government and business organizations should further develop and promote the tourism resources to boost the economy development.

References

1. Archer B, Flecher J (1996) The economic impact of tourism in the seychelles. Ann Tourism Res 23(1):32–47
2. Balaguer L, Cantavella-Jorda M (2002) Tourism as a long-run economic growth factor: the spanish case. Applied Economics
3. Chen F, Zhang Q (2009) Economic effect of regional tourism development-taking Jiangxi as an example. Economy Geography
4. Ding D, Pin N (2011) Is tourism a long-run economic growth factor? Working Paper Series
5. Kim HJ, Chen MH (2006) Soocheong "shawn" jang. tourism expansion and economic development: the case of taiwan. Tour Manag 3:217–220 (in Chinese)
6. Lee CC, Chang CP (2008) Tourism development and economic growth: a closer look at panels. Tourism Management
7. Li Xingxu MY (2004) Contribution analysis of tourism industry to economic growth in yunnan province. City Probl 12:3–10 (in Chinese)
8. Liu Changsheng JY (2008) Research on tourism development and economy growth relationship–based on all provinces in China. Tourism Sci 2:63–71 (in Chinese)
9. Nikolaos Antonakakis GF, Dragouni M (2015) How strong is the linkage between tourism and economic growth in Europe? Econ Model 7:41–45 (in Chinese)
10. Oh CO (2005) The contribution of tourism development to economic growth in the korean economy. Tour Manag 5:12–15 (in Chinese)
11. Pang Li LQ, Zheng W (2006) Study on inbound tourism and economic growth in China. Reg Res Dev 19:92–110 (in Chinese)
12. Tang CF, Tan EC (2015) Does tourism effectively stimulate Malaysia's economic growth? Tourism Management
13. Tugcu CT (2014) Tourism and economic growth nexus revisited: a panel causality analysis for the case of the mediterranean region. Tour Manag 35(2):9–18 (in Chinese)
14. Wang Liangjian HQ, Fengying Y (2010) Provincial tourism development and economic growth study based on heterogeneous panel data analysis. Econ Geogr 3:73–83 (in Chinese)
15. Zhang Na TL (2013) Panel data analysis of tourism economic effect divergence study in heilongjiang province. Econ Geogr 2:43–56 (in Chinese)

Chapter 78
A Study on Competencies Model of Executive Talents in China's Spirits Industry

Guichuan Zhou and Zeming Li

Abstract China, as one of the three ancient countries in the world that give birth to spirits cultures, takes pride in the time-honored history of Chinese spirits. Chinese spirits has currently gained great reputation at home and abroad owing to the superb traditional technique of spirits making. However, there is a mismatch between cultivation of executive talents and development of the industry. Besides, the construction of executive talent groups is troubled with various problems. From the perspective of Competencies, through empirical research approach, this paper comes up with a Competencies model of executive talents in China's spirits industry and also verifies the reliability of the model.

Keywords Competencies · Competencies model · Spirits industry · Executive talents

78.1 Introduction

China is one of the three ancient countries in the world that give birth to spirits cultures. Spirits, as the essence that passed on throughout thousands of years in China, carries memories of time-honored cultures. And now Chinese spirits has gained reputation at home and abroad thanks to superb techniques and unique styles. Since China achieves a speedy recovery from the global financial crisis, China's total GDP comes in a respectable second place in the world. And meanwhile, China's spirits industry has gained great developments. The total output of spirits in 2012 in the country reached 11.5316 kiloliters, up by 18.55 % year on year. However, it is found that two statistical data collected in 2013, including taxes and profits of China's spirits industry, present negative growths for the first time in the recent

G. Zhou (✉)
Business School of Sichuan University, Chengdu 610065, People's Republic of China
e-mail: zhouguichuan@vip.163.com

Z. Li
Chengdu Banknote Printing Company Limited, Chengdu 610065, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_78

ten years. Spirits industry is facing with severe challenges, which urgently requires the industrial transformation. Besides, spirits-making enterprises are troubled with significant problems and pressured to upgrade.

As for spirits-making enterprises, the core competence under the constantly changing circumstances lies in talents especially executives wars among enterprises. Therefore, enterprises should construct their own groups of executive talents to form their core competence, supporting them to survive and develop in intense competitions.

78.2 Literature Review

78.2.1 Competencies

The theory of competency originally put forward by McClelland [13] and then later refined by Boyatzis [3] and Spencer and Spencer [22] to be especially well suited for research and applied practice.

On the other hand, one of the key challenges in the competence literature is that there are many definitions of competence [9, 10]. Research over the past 40 years has identified several hundred competencies, yet careful scrutiny often finds a good deal of overlap in competency definitions [7]. This paper defined competencies as knowledge, skills, abilities and other characteristics that are needed for effective performance in the jobs in question [17, 20]. There are at least two key meanings or uses of it: competency as behaviours that an individual demonstrates; and, competencies as minimum standards of performance [23].

The Competencies of executive talents have been identified as a specific group of competencies relevant to the exercise of successful management. They are seen as important to business growth and success, and, an understanding of the nature and role of such competencies can have important consequences for practice. Yet, despite the supposed importance of entrepreneurial competencies, the discussion of competencies in the entrepreneurial literature is in its early stages [4].

78.2.2 Competencies Model

The use of scaled competencies is an useful and practical way to organize the behavioural manifestation of competencies. As outlined in Competency at Work [22], competencies can be behaviourally scaled along specific dimensions.

Approaches to measuring competencies have been varied, depending on assumptions and predictions. Some researchers explicitly took an antecedent perspective by attempting to delineate key knowledge or abilities thought to reflect entrepreneurial and managerial, competencies, based on reviews of literature, and then having respondents self-assess their own level of competence, or level of agreement with a competence related statement [5, 12, 21].

Other researchers who have investigated the relationship between entrepreneurial cognitions and entrepreneurial decisions and their outcomes have taken a process perspective in measuring constructs related to entrepreneurial constructs [14, 18]. In a script-cue recognition methodology adapted from Read [16] measured arrangements, willingness and ability cognitions. This approach was based on expert information processing theory, used a nominal scale where respondents must agree or disagree with given statements [15].

These years, some researchers applied the method of behavioural Event Interview to conduct an empirical study on top managers. And they constructed many Competencies Models diversely [1, 2, 6, 8, 11, 19].

78.3 Research Design

78.3.1 Competencies of Executive Talents in Spirits Industry

As Competencies is a major element of this paper, with the help of BEI (Behavioural Event Interview) raised by McClellend, this paper conducted interviews with executive talents in spirits-making enterprises to extract key competencies. Before the interview, this paper also referred to relevant literature works to set an interview outline. The interview adopted the method of structured interview.

After interviewing these executive talents, this paper conducted an analysis based on their work and initially extracted competencies of them. Then, according to the conclusion, this paper sought advice and suggestions from suggestion of HR management, administration psychology experts and spirits-making enterprises. Afterwards, the conclusion was adjusted on the basis of these suggestions. Eventually, this paper concluded 12 major competencies according to behaviours and performances of excellent executive talents (Tables 78.1 and 78.2).

78.3.2 Questionnaire Design

This paper optimized the questionnaire design through four steps to make sure its reliability and validity.

With the aim of ensuring measuring tools are highly reliable and valid, this paper conducted a theoretical analysis on Competencies and provided references for questionnaire design, including results of researches on Competencies conducted by various scholars, including McClelland, Spencer, Lifeng Zhong, Chongming Wang, Kewen Li, Hongzhang An and Mengjie Wu. Besides, mature Competencies indexes are also involved in this paper. This paper drew on these research results and thus presented the preliminary design of questionnaire based on actual conditions of spirits industry. Then, academic team members made modifications to items in the

Table 78.1 A summary on competencies of executive talents in spirits industry (1)

Competencies	Features	Behaviours and performances
Expert knowledge	Be familiar with the spirits market and know about its development trends	Know well about development trends of the spirits market and comprehend deeply changes that take place in the market
	Be familiar with knowledge and skills needed in their positions and their subordinates' positions	Be acquainted with knowledge needed in their positions and their subordinates' positions
		Be familiar with products and technologies of their enterprises
Organizational knowledge	Know well about business operations of enterprises and management function	Know well about sales performances of theirs and competitors'
		Be familiar with modern management modes
		Be good at leading an efficient and cohesive management team
Affinity	Be able to make others feel close and trustful to them	Be able to keep a positive and confident attitude when getting along with others
		Dress up decently; express and take actions naturally and gently
		Be ready to help and show cares for others
		Be broad-minded and able to accept the existence of different opinions and methods
Decision-making ability	Focus attention on relevant or important results or objectives, thus making clear decisions that benefit themselves and others	Be able to determine priorities for themselves and others cated circumstances
		Be able to measure quantitatively influences of major decisions
		Won't go with the flow
		Be able to respond to trifle things quickly

(continued)

Table 78.1 (continued)

Competencies	Features	Behaviours and performances
Leadership	Trust, train and instruct others to be able to control their destiny by themselves	Be able to encourage their subordinates to shoulder challenging work and tasks
		Be able to actively provide guidance and encouragements for their subordinates to do right things
		Be able to frequently make informal conversations with their subordinates
		Be able to leave enough space for their subordinates and enable them to present their abilities
Contingency management	Be able to adjust changes of environments; make necessary adjustments and improve management, thus making organizations smoothly undergo transformation	Be able to clearly express fruits of transformation
		Be able to assist their subordinates to understand significance of transformation
		Be able to manage and encourage transformation activists to participate in transformation
		Be able to take quick and appropriate actions to cope with resistance to transformation
Achievement orientation	Think about accomplishing set objectives alone	Consider finishing a valuable work as the greatest psychological satisfaction
		Be able to persistently pursuing objectives
		Continuously set higher goals for themselves
Market orientation	Personally be able to regard competitors, markets and customers as guidance for daily work	Be able to get timely information of markets and actions of competitors
		Be able to improve methods to satisfy and excess customers' anticipation
		Be able to recognize internal and external demands of customers
		Be able to take suggestions from customers to improve procedures

(continued)

Table 78.1 (continued)

Competencies	Features	Behaviours and performances
Innovation ability	How one can creatively collect decentralized information to form energetic and clear decisions and actions	Apply creative methods when making decisions
		Be able to view problems with divergent thinking
		Be able to combine things that seem to be unrelated and create new ideas
		Be able to creatively solve problems

Table 78.2 A summary on competencies of executive talents in spirits industry (2)

Competencies	Features	Behaviours and performances
Learning ability	Be able to swiftly understand and acquire new knowledge and skills	Have definite personal development objectives and strong desires to acquire knowledge and skills
		Be able to quickly establish connections between new and old knowledge and skills. Be quick in acquiring new knowledge and skills
		Excel in improving working method or procedures. Obviously Improve efficiency. Flexibly make use of new knowledge and skills.
Reliability	One is reliable, calm and responsible for work	Be able to be depended on
		Be able to maintain confident and brave even when troubled with difficulties
		Be responsible for behaviours
		Be able to keep promises
Team spirit	One can work with others and take advantage of different skills and experiences to form team spirits	Be able to form an efficient and steady team based on abilities and potentials
		Work with other team members to construct "bridges", thus strengthening cooperation and unity at utmost
		Be able to actively listen to others' opinions and suggestions
		Be able to show their belief and trust in team members

questionnaire that were ambiguous in meanings according to the feedback of the academic discussion and delete items that overlap with others. In addition, this paper invited some HR management experts, management psychology experts and management expertise in spirits-making enterprises to give their suggestions on it. Then the questionnaire is improved based on suggestions of experts. Finally, this paper invited some top managers in spirits-making enterprises to participate in pretest questionnaire and revised it before finalized it.

78.3.3 Research Samples

With top managers in China's spirits-making enterprises, the survey field generally covered main producing areas of spirits in China, aiming to ensuring the research samples were representational.

This paper gave out 300 questionnaires and received 225 back. In accordance with requirements of the research, the questionnaires are filtered, with 14 unqualified questionnaires being eliminated because of incompleteness or obvious mistakes and finally got 211 valid questionnaires.

78.3.4 Test on Reliability and Validity

This paper made use of SPSS to acquire Cronbach value of research variables. The reliability of total scale reaches 0.962 and the results of subscales reveals that values of the variables are all bigger than 0.7. These values indicate that all data of measured competencies are relatively reliable. Therefore, measured data of the samples are reliable and consistent for further data analysis.

Based on factor analysis, this paper tried to verify the structural validity of the questionnaire. But before applying factor analysis, it's necessary to conduct KMO and Bartlett's test to examine whether the scale is suitable for factor analysis. The results (KMO = 0.852, $x^2/df = 622.645$) show that the measured data are suitable for factor analysis. After conducting an analysis with common factor variance applies, it was discovered that the all factors had great explain ability. In addition, the cumulative variance explain ability rate is 71.95 %. And the loads of all factors are heavier than 0.5 while their cross-loads lighter than 0.4. Therefore the scale has relatively preferable structure validity.

78.4 Data Analysis

Since there were 211 valid questionnaires received, this paper randomly divided these valid questionnaires into two parts. One part concluded 105 questionnaires which were used for exploratory factor analysis. And the rest 106 questionnaires were used for confirmatory factor analysis with the purpose of verifying the accuracy of the model.

78.4.1 Exploratory Factor Analysis

Before conducting exploratory factor analysis, it's necessary to carry out KMO and Bartlett's test. The results shows apart from the communalities of reliability and decision-making ability which are relatively low, the communalities of organizational knowledge, expert knowledge, affinity, leadership, contingency management, achievement orientation, customer orientation, market orientation, innovation ability, learning ability and team spirit are above 70 %, indicating great explain ability. The results reveal that there are 4 factors whose initial eigenvalues are bigger than 1. Thus this paper extracted the four main factors. And it is also shown that the four extracted main factors have 71.95 % of total explained variance rate and they can cover main information of original variables (Table 78.3).

The results indicate that of the first common factor, the variances with high loadings include decision-making ability, learning ability, leadership and innovation ability. These variances all demonstrate abilities of executive talents. Thus the first common factor is named as "ability". Of the second common factor, the variances

Table 78.3 Rotated component matrix

	Component			
	1	2	3	4
Decision-Making ability	**0.86**	−0.038	−0.275	−0.336
Learning ability	**0.834**	−0.213	−0.045	−0.306
Leadership	**0.775**	−0.384	0.173	0.239
Innovation ability	**0.716**	−0.077	0.054	−0.014
Affinity	−0.028	**0.776**	0.271	−0.019
Reliability	−0.018	**0.754**	0.032	0.008
Achievement orientation	0.199	**0.643**	−0.064	0.064
Market orientation	0.392	−0.162	**0.779**	−0.176
Team spirit	0.321	0.342	**0.761**	−0.017
Contingency management	−0.259	0.297	**0.72**	0.11
Organizational knowledge	−0.149	−0.172	−0.328	**0.866**
Expert knowledge	−0.162	−0.004	−0.233	**0.753**

with high loadings include affinity, reliability and achievement orientation, which reflect personal qualities of executive talents. Thus the second common factor is named as “personal quality”. Of the third common factor, the variances with high loadings include market orientation, team spirit and contingency management which all reflect managing behaviours of executive talents. So the third common factor is named as “behaviour”. Of the fourth common factor, the variances with high loadings include expert knowledge and management knowledge. These variances show knowledge and skills of executive talents. Therefore the fourth common factor is named as “skill”.

To sum up, through exploratory factor analysis, this paper managed to construct a Competencies Model of executive talents in China’s spirits industry, whose structure involved four Competencies dimensions (skill, personal quality, ability and behaviour) and 12 competencies.

78.4.2 Confirmatory Factor Analysis

Based on confirmatory factor analysis which produced a Competencies Model of executive talents in China’s spirits industry, this paper verified the accuracy of the model. Confirmatory factor analysis included verification of internal consistency reliability, structure validity, convergent validity, discriminate validity and content validity. Since the scales measured in the research were rooted in literary works, this paper repeatedly made modifications based on actual research results, which also improved the content validity. Therefore, this paper made use of Lisrel to analyze the data:

(1) Structure Validity

This paper mainly chose x^2/df, GFI, CFI and RMSEA as standards of verification. As conclusions, x^2/df is 2.34, which indicates that the Competencies Model is relatively acceptable. GFI value is 0.81, revealing that the model fitting with the sampled data is qualified. Besides, CFI value is 0.87, demonstrating that the Competencies Model is fitted relatively well. In addition, RMSEA value is 0.06, between 0.05 and 0.08. These values manifest that the Competencies Model is quite fitted and equipped with great structure validity.

(2) Verification of Internal Consistency Reliability

Table 78.4 indicates that the smallest Cronbach α value of the four Competencies dimensions is 0.85, much bigger than 0.7, which means that the scale is highly consistent internally.

(3) Discriminant Validity

Table 78.4 reveals that the correlation coefficients of the four Competencies dimensions in the Competencies Model of executive talents in China’s spirits industry are all smaller than Cronbach α values, which indicates that the model maintains high internal consistency. Meanwhile, the correlation among the four Competencies

Table 78.4 E-procurement challenges and key advantages

Competencies	M ± SD	Correlation coefficient	Cronbach α
Skill	3.31 ± 0.66	0.63	0.85
Personal quality	3.41 ± 0.61	0.68	0.88
Behaviour	3.21 ± 0.58	0.69	0.91
Ability	3.28 ± 0.61	0.68	0.87

dimensions—skill, personal quality, behaviour and ability—is relatively small and these competencies have their own independent meanings. Therefore, the dimensions have great discriminant validity.

In a word, confirmatory factor analysis conclusion proves that the Competencies Model of executive talents in China's spirits industry is a reliable model.

78.5 Conclusion

This paper applied SPSS and Lisrel to analyze the research data and extract 4 competencies through exploratory factor analysis, which were named as skill, personal quality, behaviour and ability. And constructed a Competencies Model according to the four Competencies dimensions and 12 specific competencies (expert knowledge, organizational knowledge, affinity, leadership, contingency management, achievement orientation, customer orientation, market orientation, innovation ability, learning ability, team spirits, reliability and decision-making ability) and verifies the reliability of the model. The conclusion will help Chinese spirits-making enterprises to construct their own groups of executive talents to form their core competence, supporting them to survive and develop in intense competitions.

References

1. Ahmad A, Kausar AR, Azhar SM (2015) HR professionals' effectiveness and competencies: a perceptual study in the banking sector of Pakistan. Int J Bus Soc 16(2):201
2. Bamiatzi V, Jones S et al (2015) The role of competencies in shaping the leadership style of female entrepreneurs: the case of north west of England, Yorkshire, and North Wales. J Small Bus Manag 53(3):627–644
3. Boyatzis RE (1982) The competent manager: a model for effective performance. Wiley, New York
4. Brinckmann J (2008) Competence of top management teams and success of new technology-based firms. Springer, Heidelberg
5. Chandler GN, Jansen E (1992) The founder's self-assessed competence and venture performance. J Bus Ventur 7(3):223–236
6. De Vos A, De Hauw S, Willemse I (2015) An integrative model for competency development in organizations: the flemish case. Int J Hum Resour Manag 26(20):2543–2568

7. Emmerling R, Boyatzis RE et al (2012) Development and validation of a customized competency-based questionnaire: Linking social, emotional, and cognitive competencies to business unit profitability. Int J Cross Cult Manag 19(1):90–103
8. González-González I, Jiménez-Zarco AI (2015) Using learning methodologies and resources in the development of critical thinking competency: an exploratory study in a virtual learning environment. Comput Hum Behav 51:1359–1366
9. Hayton JC, Kelley DJ (2006) A competency-based framework for promoting corporate entrepreneurship. Hum Resour Manag 45(3):407–427
10. Hoffmann T (1999) The meanings of competency. J Eur Ind Training 23(6):275–286
11. Lo K, Macky K, Pio E (2015) The hr competency requirements for strategic and functional hr practitioners. Int J Hum Resour Manag 26(18):2308–2328
12. Markman GD, Balkin DB, Baron RA (2002) Inventors and new venture formation: the effects of general self-efficacy and regretful thinking. Entrepreneurship Theory Pract 27(2):149–165
13. McClelland DC (1973) Testing for competence rather than for "intelligence". Am Psychol 28(1):1
14. Mitchell RK, Smith JB et al (2002) Are entrepreneurial cognitions universal? assessing entrepreneurial cognitions across cultures. Entrepreneurship Theory Pract 26(4):9–33
15. Mitchelmore S, Rowley J (2010) Entrepreneurial competencies: a literature review and development agenda. Int J Entrepreneurial Behav Res 16(2):92–111
16. Read SJ (1987) Constructing causal scenarios: a knowledge structure approach to causal reasoning. J Pers Soc Psychol 52(2):288
17. Rodriguez D, Patel R et al (2002) Developing competency models to promote integrated human resource practices. Hum Resour Manag 41(3):309–324
18. Shepherd DA (1999) Venture capitalists' introspection: a comparison of "in use" and "espoused" decision policies. J Small Bus Manag 37(2):76
19. Shi K, Zhong L (2003) New development researches of competencies. Nankai Bus Rev 6(2):4–8 (In Chinese)
20. Shippmann JS, Ash RA et al (2000) The practice of competency modeling. Pers Psychol 53(3):703–740
21. Smith B, Morse E (2005) Entrepreneurial competencies: literature review and best practices., Small Business Policy BranchIndustry Canada, Ottawa
22. Spencer LM, Spencer PSM (2008) Competence at work models for superior performance. Wiley, New York
23. Strebler M et al (1997) Getting the best out of your competencies. ERIC

Chapter 79
College Student Satisfaction Index in China: Model and Empirical Research

Xiangqing Chen

Abstract According to the current situation of higher education in China, this paper builds a College Student Satisfaction Index model on the basis of ACSI and ECSI. Some structural variables such as information, perceived cost, college image, student expectation, perceived quality, perceived value, student complaint, student satisfaction, and student loyalty. An empirical research on the model is carried out by the questionnaire survey to the freshmen from colleges in Foshan, China. The results show that, expectancy disconfirmation mode and perceived value mode jointly influence student satisfaction; perceived quality and perceived cost have significant effects on student satisfaction through perceived value as a intermediate variable; and the introduction of information and college image variables is helpful to explaining the relationships among student expectation, student satisfaction and student loyalty more reasonably, etc. Some suggestions are put forward, such as enhancing the publicity and promotion, strengthening cost control, raising value perception of college student, and so on.

Keywords College student satisfaction index · College image · Perceived cost · Perceived value · Higher education

79.1 Introduction

The study on evaluating of college student satisfaction started in America in 1960s. More than half a century later, it has developed into relatively mature theories, systems and methods in developed countries such as America and England, and so on. In recent years, some scholars began to pay close attention to the investigation and research of college students satisfaction in China, and have made certain achievements in the theory and practice. The research mainly focused on the two aspects,

X. Chen (✉)
Department of Business Administration, Foshan Polytechnic, Foshan 528137, People's Republic of China
e-mail: chenxiangq@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_79

the first was mainly concerning the measuring of degrees and dimensions of college student satisfaction, the second was the modeling and empirical study based on the framework of Customer Satisfaction Index (CSI). Although the researchers confirmed the importance of evaluation on college student satisfaction, doubtlessly there were deficiencies. The former paid too much attention to the micro level, with too many variables and questions involved in. It was difficult to carry out a large-scale evaluation, and is not conducive to horizontal comparison; the latter was too dependent on the ACSI and ECSI in the model construction, with the deficiencies in combining with the characteristics of higher education in China. Further study is required.

College student satisfaction survey is an important means of strengthening higher education quality management in the world, especially in developed countries. With the rapid development of higher education and the gradually increasing quality awareness in China, the evaluation on college student satisfaction is becoming more and more urgent. However, the study on the college student satisfaction in China is rather weak at present, and a national measurement system has not been set up due to some key problems pending to be solved. This paper constructs an evaluation model of College Student Satisfaction Index based on the core concepts of ACSI (American Customer Satisfaction Index) and ECSI (European Customer Satisfaction Index), with full consideration of the behavior characteristics of college students in China. An empirical research on the model is made by the questionnaire survey to the freshmen from colleges in Foshan, China. The aims are to push through the application of student satisfaction evaluation in the colleges and to improve the quality of higher education management in China.

79.2 Specification of Model

79.2.1 Construction of Model

The comparison criterions on formation mechanism of customer satisfaction include the expectancy disconfirmation mode, need disconfirmation mode, perceived performance mode, and perceived equity mode, etc., among which, expectancy disconfirmation" is the mainstream mode of satisfaction evaluation at present. According to this theory, whether student is satisfied depends on the degree of the disconfirmation between expectation and perceived quality. If perceived quality exceeds expectation, the student will feel satisfied. The study of Liu confirmed student expectation towards college positively influenced student satisfaction [8]. The empirical analysis of Hishamuddin et al. [5] found perceived quality of student had significant effects on student satisfaction. According to Sadeh et al. [12], in the field of higher education, every dimension of perceived service quality of student was closely related to student satisfaction. Based on the above viewpoints, the variables of student expectation, perceived quality and student satisfaction are introduced to the model and the following hypotheses are built:

Hypothesis 1 (H1) Student expectation has direct effects on perceived quality.

Hypothesis 2 (H2) Student expectation has direct effects on student satisfaction.

Hypothesis 3 (H3) Perceived quality has direct effects on student satisfaction.

College image is the overall impression of student towards a college. As for a college freshman, the college image may be formed through the active information collection as well as unconscious information communication and accumulation via all kinds of channels, such as the introduction of teachers, the recommendation of friends and relatives, the personal experience himself, the reports of network media, on-the-spot investigation, etc. Student will form an impression towards a college based on the above information and has different expectation to different college. General speaking, the better college image, the higher student expectation, and the higher student satisfaction and student loyalty. According to the research of Yang et al. [14], the college image had significant influence on student expectation, student satisfaction and student loyalty. Other scholars, including Temizeret et al. [13] and Duarte et al. [3], had the similar conclusion. Based on the above studies, information and college image variables are introduced to the model and the following hypotheses are built:

Hypothesis 4 (H4) Information has direct effects on student expectation.

Hypothesis 5 (H5) Information has direct effects on college image.

Hypothesis 6 (H6) College image has direct effects on student expectation.

Hypothesis 7 (H7) College image has direct effects on student satisfaction.

Hypothesis 8 (H8) College image has direct effects on student loyalty.

The variable of perceived value is introduced to most existing customer satisfaction evaluation models, for example, in the ACSI model, customer satisfaction is at the center of the model, and perceived quality, perceived value and customer expectation jointly influence customer satisfaction [4, 7]. However, the existing models fail to handle the relationships among customer expectation, perceived quality, perceived value and customer satisfaction properly [10]. The core of perceived value variable is the comparison between perceived quality and perceived cost, instead of the comparison between perceived quality and customer expectation in the traditional models. Thus, a relatively independent perceived value mode is introduced to the model. That is, perceived quality and perceived cost influence on student satisfaction through perceived value as a intermediate variable. Based on the above analyses, perceived value and perceived cost variables are introduced to the model and the following hypotheses are set up:

Hypothesis 9 (H9) Perceived cost has direct effects on perceived quality.

Hypothesis 10 (H10) Perceived cost has direct effects on perceived value.

Hypothesis 11 (H11) Perceived quality has direct effects on perceived value.

Hypothesis 12 (H12) Perceived value has direct effects on student satisfaction.

As for the result of satisfaction, both Ruyter [2] and Lanee [1] believed that customer satisfaction is an important factor influencing customer loyalty. The empirical study of Angelos et al. [11] showed that customer satisfaction is a middle variable between perceived quality and customer loyalty. According to "Complaint-Exit theory" of Hirschman [6], customer satisfaction negatively influenced customer |hboxcomplaint, but positively influenced customer loyalty. A lot of empirical studies of Chinese scholars have similar conclusion [9, 15]. These research outcomes will provide references for the model construction of student satisfaction index. Based on the above analysis, student complaint, student satisfaction and student loyalty variables are introduced to the model and the following hypotheses are put forward:

Hypothesis 13 (H13) Student satisfaction has direct effects on student loyalty.

Hypothesis 14 (H14) Student satisfaction has direct effects on student compliant.

Hypothesis 15 (H15) Student compliant has direct effects on student loyalty.

79.2.2 Evaluation Method and Indicators of Model

Based on the above hypotheses, a new evaluation model of College Student Satisfaction Index is constructed (refer to Fig. 79.1). The model includes nine structural variables, which are perceived cost (COST), information (INFO), college image (IMAG), perceived quality (QUAL), perceived value (VALU), student expectation (EXPE), student complaint (COMP), student satisfaction (SATI) and student loyalty (LOYA), among which the information and perceived cost are exogenous variables and the others are endogenous variables. 9 structural variables correspond to 25 observable variables (manifest variables), which are designed mainly based on the international mature scales to increase the accuracy and efficiency. In addition, some bold innovations are joined into the observable variables, e.g., the information variable is measured by the sufficiency and the effectiveness of information, and the college image variable is measured by the awareness, reputation and general image

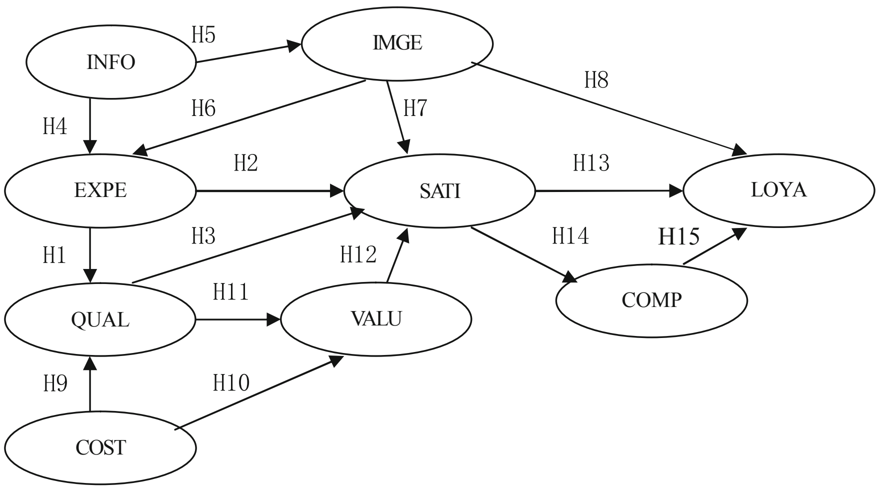


Fig. 79.1 The model of college student satisfaction index in China

of college; perceived cost is measured through the perception of entrance scores, the perception of tuition, and the perception of total cost; student loyalty is measured by the possibility of recommending the college to others, endurance capacity of change of entrance scores and the endurance capacity of change of tuition, etc.

79.3 Empirical Analysis

79.3.1 Data Sources

The study has chosen some freshmen from several colleges in Foshan by systematic sampling for questionnaire investigation. There are 679 questionnaires collected, among which there are 605 effective questionnaires, with an effective percentage of 89.1 %. Samples of investigation data are distributed as follows: 42.8 % are male students, 57.2 % are female students; 14.2 % are the only child of a family and 85.8 % are not the only child of a family; 54.2 % come from rural area, 29.6 % come from small town (at the county level and below), 16.2 % come from large or medium city (at prefecture level and above); 68.9 % are liberal arts students, and 31.1 % are science students.

79.3.2 Descriptive Statistic Analysis

The study uses SPSS22.0 to carry out descriptive analysis on 25 observable variables involved in the questionnaire. The results are as shown in Table 79.1.

Table 79.1 The mean and stdev of observable variables

Index	Mean	Stdev	Index	Mean	Stdev	Index	Mean	Stdev	Index	Mean	Stdev
X1	4.863	2.225	Y3	5.889	2.204	Y10	5.344	2.344	Y17	4.488	2.582
X2	5.443	2.319	Y4	6.208	2.063	Y11	5.448	2.127	Y18	5.003	2.548
X3	5.914	2.217	Y5	5.805	2.111	Y12	5.61	2.302	Y19	4.878	2.511
X4	5.755	2.261	Y6	6.121	2.048	Y13	5.179	2.383	Y20	4.159	2.498
X5	5.721	2.196	Y7	3.788	2.533	Y14	5.626	2.33			
Y1	5.742	2.229	Y8	4.764	2.405	Y15	6.015	2.248			
Y2	5.658	2.213	Y9	5.488	2.35	Y16	5.825	2.423			

79.4 Examination of Measuring Model

79.4.1 Reliability Analysis

SPSS22.0 is used to get the reliability coefficient (Cronbach α) of structural variables, as shown in Table 79.2. The reliability coefficient of nine structural variables in the scale are scored 0.70 and above, and the reliability coefficient of the total scale reaches 0.946, the composite reliability of nine structural variables reaches from 0.719 (COMP) to 0.909 (VALU), all above 0.6, indicating that the scale has high reliability.

79.4.2 Confirmatory Factor Analysis

The study use software LISREL8.80 to carry out confirmatory factor analysis on the measuring model, and the results of analysis are as shown in Table 79.3. The factor load coefficients of 25 variables are from 11.63 to 24.68 (t-value), and the average variance extracted of 9 structural variables are higher than 0.50, indicating

Table 79.2 The reliability coefficient and composite reliability of structural variables

Structural variable	INFO	COST	EXPE	QUAL	IMGE	VALU	SATI	COMP	LOYA	Total
Number of variables	2	3	3	3	3	2	4	2	3	25
Reliability coefficient	0.712	0.791	0.783	0.827	0.779	0.798	0.892	0.703	0.867	0.946
Composite reliability	0.727	0.794	0.834	0.824	0.787	0.909	0.854	0.719	0.866	–

Table 79.3 Convergent validity analysis of measuring model

Structural variable	INFO	COST	EXPE	QUAL	IMGE	VALU	SATI	COMP	LOYA
EXPE	**0.567**	0.472	0.51	0.315	0.304	0.196	0.266	0.423	0.263
QUAL	0.687	**0.539**	0.415	0.463	0.489	0.319	0.472	0.448	0.401
IMGE	0.714	0.644	**0.555**	0.329	0.416	0.234	0.373	0.724	0.338
VALU	0.561	0.681	0.574	**0.77**	0.461	0.355	0.527	0.402	0.495
SATI	0.551	0.699	0.645	0.679	**0.661**	0.41	0.653	0.44	0.456
COMP	0.443	0.565	0.484	0.596	0.64	**0.506**	0.354	0.154	0.293
LOYA	0.516	0.687	0.611	0.726	0.608	0.595	**0.684**	0.361	0.407
INFO	0.65	0.669	0.851	0.634	0.663	0.392	0.601	**0.545**	0.466
COST	0.513	0.633	0.581	0.704	0.675	0.541	0.638	0.683	**0.563**

good convergent validity. Among the 36 shared variances, 33 are less than 0.50. The shared variances among variables are less than or close to its average variance extracted, and the classification validity of the model is acceptable.

79.4.3 Examination of Structural Model

It is shown from the fitting degree of data and the model that χ^2 of the measuring model is 1079.551 (308 degrees of freedom), $\chi^2/df = 3.505 < 5.00$, $SRMR = 0.059 < 0.08$, $RMSEA = 0.073 < 0.08$; other index including NFI, NNFI, PNFI, CFI, IFI, RFI, GFI, AGFI, PGFI are 0.960, 0.964, 0.943, 0.968, 0.968, 0.955, 0.936, 0.899 and 0.821 respectively, all reaching or close to 0.9, indicating that the model and data have a high fitting degree.

79.5 Results and Discussion

We use software LISREL 8.80 to attain the path coefficient among variables in the model (as shown in Table 79.4). The details of analysis are as follows:

(1) Overall, the model fits well and the statistics of path coefficients are significant. The t values of all path coefficients in the model are from 3.457 to 13.899, indicating that the statistics of path coefficients are significant ($P = 0.00$). The highest value of direct effect from all paths reaches 0.784 (information to college image), and the lowest value is −0.267 (student satisfaction to student complaint), showing a negative influence. It is shown that sufficient and effective information is the key factor affecting college image. Therefore, colleges shall use Internet, media, and the public praise from students to enhance the publicity and promotion for their colleges, and establish a good image among students, which is beneficial to the improvement of student satisfaction and student loyalty.

(2) The mode of influence of perceived cost and perceived quality on perceived value is verified. According to the research data, the direct effect from perceived cost to perceived quality is 0.539 (10.384), the direct effect from perceived cost to perceived value is 0.471 (7.820), the direct effect from perceived quality to perceived value is 0.439 (7.375), and the direct effect from perceived value to student satisfaction is 0.614 (8.779), with significant statistics of effects from all paths ($P = 0.00$). It shows that perceived quality and perceived cost have an effect on student satisfaction through perceived value as a intermediate variable, which is easier to differentiate the contribution of the expectancy disconfirmation mode and the perceived value mode to the student satisfaction respectively. Thus, in addition to emphasizing on helping student to set up a reasonable expectation, it is very important for higher education to strengthen cost control and to help

Table 79.4 Direct effect, indirect effect and complete effect of structural variables in the model

	INFO	COST	EXPE	QUAL	IMGE	VALU	SATI	COMP	LOYA
EXPE									
Direct effect	0.204				0.534				
Indirect effect	0.419								
Complete effect	0.623				0.534				
QUAL									
Direct effect		0.539	0.453						
Indirect effect	0.282				0.242				
Complete effect	0.282	0.539	0.453		0.242				
IMGE									
Direct effect	0.784								
Indirect effect									
Complete effect	0.784								
VALU									
Direct effect		0.471		0.439					
Indirect effect	0.124	0.237	0.199		0.106				
Complete effect	0.124	0.708	0.199	0.439	0.106				
SATI									
Direct effect			−0.244	0.284	0.244	0.614			
Indirect effect	0.198	0.587	0.251	0.27	0.004				
Complete effect	0.198	0.587	0.007	0.554	0.248	0.614			
COMP									
Direct effect							−0.267		
Indirect effect	−0.053	−0.157	−0.002	−0.148	−0.066	−0.164			
Complete effect	−0.053	−0.157	−0.002	−0.148	−0.066	−0.164	−0.267		
LOYA									
Direct effect					0.129		0.576	−0.158	
Indirect effect	0.223	0.363	0.004	0.342	0.153	0.379	0.042		
Complete effect	0.223	0.363	0.004	0.342	0.282	0.379	0.618	−0.158	

student to set up reasonable cost perception, which is benefit to improve student satisfaction and loyalty.

(3) The introduction of information and college image as variables is verified. The model includes two structural variables—information and college image. There are two paths come from information the direct effect from information to student expectation is 0.204 (5.384) and the direct effect from information to college image is 0.784 (13.899); there are three paths come from college image: the direct effect from college image to student expectation is 0.534 (5.750), from college image to student satisfaction is 0.244 (4.535), and from college image to student loyalty is 0.129 (4.318). The effects of all paths are statistically sig-

nificant ($P = 0.00$). Therefore, it is reasonable and necessary to introduce the variables of information and college image and set up relevant path relations, which is beneficial to a more reasonable explanation of the relations of student expectation, student satisfaction and student loyalty.

79.6 Conclusion

Based on the core concepts of ACSI and ECSI, combined with the research outcomes on student satisfaction both in China and abroad, a new model of College Student Satisfaction Index is built. Some innovations are put forward in the new model, mainly include: the variables introduction of information, college image and perceived cost, in addition to the construction of relevant paths; the construction of relatively independent perceived value mode and expectancy disconfirmation, etc. The results of empirical research show that, expectancy disconfirmation mode and perceived value mode jointly influence student satisfaction; perceived quality and perceived cost have significant effects on student satisfaction through perceived value as a intermediate variable; and the introduction of information and college image variables is helpful to explaining the relationships among student expectation, student satisfaction and student loyalty more reasonably. However, there are some deficiencies in the quantity and representation of the samples, and further study is required for the construction of this index.

Acknowledgments Financed by Education Science Fund of Guangdong, Project Title: Market Survey Technology Curriculum Based on OBE (Project No.: 2013JK292).

References

1. Bettencourt LA (1997) Customer voluntary performance: customers as. J Retail 73(3):383–406
2. De Ruyter K, Bloemer J (1999) Customer loyalty in extended service settings: the interaction between satisfaction, value attainment and positive mood. Int J Serv Ind Manag 10(3):320–336
3. Duarte PO, Raposo MB, Alves HB (2012) Using a satisfaction index to compare students satisfaction during and after higher education service consumption. Tert Educ Manag 18(1):17–40
4. Fornell C, Johnson MD et al (1996) The american customer satisfaction index: nature, purpose, and findings. J Mark 60:7–18
5. Hasan HFA, Ilias A et al (2009) Service quality and student satisfaction: a case study at private higher education institutions. Int Bus Res 1(3):163
6. Hirschman AO (1970) Exit, voice, and loyalty: responses to decline in firms, organizations, and states. Mass: Harvard University Press, Cambridge
7. Johnson MD, Gustafsson A et al (2001) The evolution and future of national customer satisfaction index models. J Econ Psychol 22(2):217–245
8. Liu X (2011) The survey report of student satisfaction in higher vocational education with SEM. High Educ Forum 34:75–77 (in Chinese)
9. Liu X (2011) The theory of differentiation on student satisfaction in higher vocational education. Vocat Educ Res 1:69–71 (in Chinese)

10. Mikulić J, Duževič I, Baković T (2014) Exploring drivers of student satisfaction and dissatisfaction: an assessment of impact-asymmetry and impact-range. Total Qual Manag Bus Excellence (ahead-of-print):1–13
11. Pantouvakis A, Bouranta N (2013) The interrelationship between service features, job satisfaction and customer satisfaction: evidence from the transport sector. TQM J 25(2):186–201
12. Sadeh E, Garkaz M (2014) Explaining the mediating role of service quality between quality management enablers and students' satisfaction in higher education institutes: the perception of managers. Total Qual Manag Bus Excellence (ahead-of-print), pp 1–22
13. Temizer L, Turkyilmaz A (2012) Implementation of student satisfaction index model in higher education institutions. Procedia Soc Behav Sci 46:3802–3806
14. Yang X, Liu W (2006) The model and the application chinese higher education customer satisfaction index. Liaoning Educ Res 10(2):7–10 (in Chinese)
15. Zhao Y, Han Z (2007) The model of high school customer satisfaction on structure equation. Syst Eng 11:85–90 (in Chinese)

Chapter 80
Size Effect, Neighbour Effect and Peripheral Effect in Cross-Border Tax Games

Xin Liu

Abstract This paper analyses a game theoretic model of taxation competition in a system where tax authorities are revenue optimisers and sovereign countries are differentiated in country sizes. Model setting accommodates more than two countries. Such an economy is characterised in an equilibrium where the large countries set higher tax rates in non-cooperative context. The sizes of the countries in the neighbourhoods show a positive relation with equilibrium tax rates. By applying the Hotelling linear model, this paper gives examples that size effect, neighbourhood effect and peripheral effect coexist and push up the tax rate in equilibrium.

Keywords Tax competition · Cross-border shopping · Nash equilibrium · Peripheral effects

80.1 Introduction

A casual observation on Chinese internet shopping shows an interesting phenomenon. Type purchase intermediate/agent (in Chinese) in Taobao, the biggest Chinese and arguably international on-line retail platform, you may find over 70 million results (A random search showed 71469345 items on www.taobao.com, the top on-line shopping platform in China, at 11:37am., 2nd, April, 2014.). The tariff and retail tax combined make the commodity price relatively higher than the international price. Hong Kong is another way to avoid the high tax. Mainland Chinese travel to Hong Kong not just for tourist pleasure, but also, if not more importantly, for shopping. The targets range from luxury accessories to basic food, even for milk. The price difference between mainland China and Hong Kong may be higher than the aggregate of plane tickets and overnight Hong Kong accommodation, which is considered to be the most expensive in the world. This kind of outward cross-border shopping

X. Liu (✉)
Department of Economics, School of Economics and Business Administration, Chongqing University, Chongqing 400044, People's Republic of China
e-mail: liuxin@cqu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_80

is so big that the Chinese tax authority (custom and tax bureau) is thinking about lowering tariff and tax. Hong Kong is not the unique example. The generosity of Chinese customers becomes well known in Korea, Japan and most of neighbouring Asian countries. However, a simple fact is that the demand of China is bigger than any other Asian countries, and the difference will be even bigger in the foreseeable future. This is not a unique case in tax distribution.

In the European gasoline price index (All data are given in Rietveld, van Woudenberg, 2005), a country's petrol price seems related to its neighbors' geographic size, as well as its own. The Western European countries seem to have relatively higher petrol prices than the rest. France, which is the biggest country located at the middle of this group, has one of the highest prices, at 111 US Cents. The low-petrol-price countries agglomerate in the Eastern Europe, in which Romania has the lowest price at 53 US Cents, only half high of French petrol price. As the petrol price is largely related to the countries' taxation policies, we can have a glance at the European tax rates distribution in this petrol price index (We do not include European countries, which are not member of EU, into this observation, e.g., Turkey and Russia. This is because their citizens cannot enjoy free cross-border traveling or shopping. We draw non-Schengen-Agreement Member states from this observation, e.g., the UK and the Republic of Ireland. Because visa is still needed for their citizens' European travel.). While the countries own sizes' influence on the tax rates have been explored heavily, little attention has been devoted to the question of the neighbourhoods' influence on tax distribution.

Two questions are of particular interest. What is the country's size effect on fiscal policies? What is the neighbourhoods' effect on fiscal policies? In fact, combination of above questions is essence of geographic fiscal competition studies.

Kanbur and Keen [4] initiated the study on commodity tax competition in a model of tax competition between sovereign governments. The authors argue that countries with higher population density tends to set higher tax rate. Ohsawa [8] modelled a linear economy argues that geographically bigger country sets higher tax rate. Piertii and Wang [11] introduced dynamic game into tax competition. Nielsen [7] implanted transportation costs. Ohsawa and Koshizuka [8] modelled the tax competition in a two-dimensional model. Bhaskar and To [1] proposed a model of wage dispersion in oligopsonistic competition in the labour market, where they deduced the equilibrium wage distribution. The techniques of linear system analyses facilitate to seek unique PSNE in a model of n countries. Liu and Madden [5] studied countries differentiated in both size and population density. Non-pure-strategy-equilibrium was found, and the results from mixed strategy equilibrium violated the previous observation that bigger country sets higher tax rate.

The purpose of this paper is to study tax competition amongst more than 2 tax authorities. We examine how the sizes of the countries (both in land sizes and in population) and their locations affect tax rates. The tax authorities of the countries are considered as players in tax game. We are interested in the answers to the two essential questions above: What is the country's size effect on fiscal policies? What is the neighborhoods' effect on fiscal policies?

The rest of this paper is organized as follows. In Sect. 80.2, we formulate our general Salop tax competition model. Section 80.3 analyses the equilibrium. Section 80.4 models a Hotelling linear economy, and studies the coexistence of size effect, neighbor effect and peripheral effect. Section 80.5 concludes this paper.

80.2 Model

We consider a circular world, where $n(n \geq 2)$ countries are located on the circumference of a circle. Those countries divide the circular world into n adjacent and non-overlapping segments. The segment of represent the land of $[0, L_0]$ country 0, $[L_0, L_1]$ represent the land of country 1, $[L_i, L_{i+1}]$ represent the land of country i, and so on and so forth. Each country has two neighbors, one to each side, i.e., country i is neighboring country $i+1$ and country $i-1$, country 0 is neighboring country $n-1$ and country 1. The population of country i is $A_i > 0$. The population is uniformly distributed over the whole world with density δ, which is normalized to unity without loss of generality. Notice that $A_i = \delta \cdot Ł_i = L_i$.

Firms are located at each every point in all countries distributed in a continuum. All firms are producing one single type of consumable goods at a constant marginal cost C. We normalize the marginal cost to zero without loss of generality, i.e., $C = 0$. The production is able to meet all consumers wish to buy at their residence. As assumed in paper 2, all individual in the world wishes to buy one and only one unit of commodity inelastically. The consumers can either purchase domestic product without travelling, or shop at the border purchasing imported goods. In the latter case, a travelling cost of $\gamma \times x$ occurs to travel a distance x.

The governments of all countries impose commodity taxes on the purchase. Country i levies a tax of p_i for per unit of the goods from the consumer. Given the assumptions that the firms are located in a continuum and that the marginal cost normalized to zero, Betrand competition result in a pricing equilibrium of p_i inside the sovereign border of country i. Residents in country i have to travel to the border to make cross-border shopping from country $i+1$ or country $i-1$, where the total cost will be $p_{i+1} + \gamma \times x$ or $p_{i-1} + \gamma \times x$ if she has to travel a distance of x from home. If the tax rates are identical between neighboring countries, where $p_i = p_{i+1}$, there will be no cross-border shopping between country i and $i+1$. If $p_i \geq p_{i+1}$, there will be outwards cross-border shopping from country i equal to the quantity such that

$$C_i(p_i - p_{i+1}) = \min\{(p_i - p_{i+1})\,|\gamma\ , A_i\}. \tag{80.1}$$

Governments are maximizing the tax revenue by adjusting tax rates. Thus we can form a simultaneous move non-cooperative tax game as:

$$\pi_i(p_0, \ldots, p_{n-1}) = p_i D_i = \left(L_i + \frac{1}{\gamma}(p_{i-1} + p_{i+1} - 2p_i)\right) \times p_i. \tag{80.2}$$

80.3 Salop Equilibrium

Notice that the payoff function given by Eq. (80.2) is a strictly concave function. Thus this globally strictly concavity enable the existence of a pure strategy Nash equilibrium.

The first order condition of π_i with respect to p_i gives the best response function:

$$p_i = \frac{1}{4}(\gamma L_i + p_{i-1} + p_{i+1}). \tag{80.3}$$

Rearranging the best response equation, we get

$$-\frac{1}{4}p_{i-1} + p_i - \frac{1}{4}p_{i+1} = \frac{1}{4}\gamma L_i. \tag{80.4}$$

Based on Eq. (80.2), we let $B = \begin{bmatrix} 1 & -\frac{1}{4} & 0 & \cdots & -\frac{1}{4} \\ -\frac{1}{4} & 1 & -\frac{1}{4} & \cdots & 0 \\ 0 & -\frac{1}{4} & 1 & -\frac{1}{4} & \cdots \\ 0 & \cdots & \cdots & \cdots & 0 \\ -\frac{1}{4} & 0 & \cdots & -\frac{1}{4} & 1 \end{bmatrix}$ and $A = \frac{1}{4}\gamma \begin{bmatrix} L_0 \\ L_1 \\ \cdots \\ L_{n-1} \end{bmatrix}$.

The equilibrium tax rate is

$$p = B^{-1}A. \tag{80.5}$$

Notice that B is a symmetric circulant matrix, ensuring the existence of a unique Nash equilibrium.

Proposition 80.1 *There always exists a unique Nash equilibrium, given by* $P^* = B^{-1}A$.

Define a notation m that there are m neighbors on either side of i, which are $i's$ neighbors, where $m \in [0, n/2]$ when n is even, and $m \in [0, (n-1)/2]$ if n is odd. Let $\sharp m(i)$ be the number of large countries in country $i's$ neighborhood. Define the expression $i\Delta j$ where for some $m*$, if $m = m^*$, then $\sharp m(i) > \sharp m(j)$, and if $m < m^*$, then $\sharp m(j) = \sharp m(i)$. The intuition is that if $i\Delta j$, there are more large countries located the closest to country i than those closest to country j.

Define a notation m that there are m neighbors on either side of i, which are $i's$ neighbors, where $m \in [o, n/2]$ when n is even, and $m \in [o, (n-1)/2]$ if n is odd. Let $\sharp m(i)$ be the number of large countries in country $i's$ neighborhood. Define the expression $i\Delta j$ where for some m^*, if $m = m^*$, then $\sharp m(i) > \sharp m(j)$, and if $m < m^*$, then $\sharp m(j) = \sharp m(i)$. The intuition is that if $i\Delta j$, there are more large countries located the closest to country i than those closest to country j.

For example, if country j is a big country, and country $j-1$ and $j+1$, which are neighboring j geographically, are both small country, then $\sharp 1(j) = 1$, where $m \geq 1$. If country j is a small country, $\sharp 1(j) = 0$. If country j is a big country, $j+1$ is also a big country, and $j-1$ is small, then $\sharp 2(j) = 2$.

We define S_h such that when n is odd, $S_h = 2\sum_{j=h}^{(n-1)/2} q_{0,j} + q_{0,\frac{n-1}{2}}$, or $S_h = 2\sum_{j=h}^{n/2} q_{0,j}$ when n is even. The intuition is that S_h is the summation of the weights ($q_{0,j}$) associated with all the countries' neighbors which are h places away or further.

Proposition 80.2 (See proof in appendix) *If $i\Delta j$, then $p_i > p_j$. If neither $i\Delta j$ nor $j\Delta i$, then $p_i = p_j$.*

There are two major implications from Proposition 80.2. Firstly, the country size is positively related to the country's tax rate. A big country will always set a higher tax rate than a small country.

The second implication suggests that the number of big countries in the neighborhood is positively related to the country's tax rate, and the number of small countries is negatively related to the tax rate. Less attention was devoted to the study of geographic environment on sovereignty country's taxation policy. Here we suggest that the location of the country plays an important role, just second to its own geographic characteristic, in the country's taxation decision. The intuition is that if a country is surrounded by big countries, it tends to set higher tax rate, while a country surrounded by small countries incline to set lower tax rate.

Examples may help us understand the property of Propositions 80.1 and 80.2. We model the k-group world as following. Half of the countries are large countries at size L_L, and the rest of them are small. Suppose that there are k large countries located contiguously on the circle, followed by k small countries, followed by k large countries, followed by k small countries, and so on and so forth. Here k denotes the number of the countries of the same size located together as a group.

Without loss of generality, we locate the first k large countries from the point 0 on the circumference, which are followed by k small countries. The second group of countries are followed by k large countries, which are followed by k small countries, and so on and so forth. Thus all n countries are located adjacently without overlapping area on the circumference, where each country has two neighbors.

Proposition 80.3 *In the k-group model, we argue that:*

(1) The size of the country is positively related to its tax rate.

(2) The number of the adjacent large countries is positively related to the tax rate of the country.

Proposition 80.3 is the ramification of Proposition 80.2 in the k-country model context. Three corollaries occur.

Corollary 80.1 *Big countries set higher tax rates than small countries, i.e., if i is big country, and j is small country, then $p_i > p_j$ (This is the extreme case in the Proof of Proposition 80.2).*

Corollary 80.2 *Inside the group of large countries, the country (when n is odd) or the two countries (when n is even) at the geographical middle of the group set the* *highest tax rate. The tax rates decline from the middle to each end. The two countries bordering the small countries' group set the lowest tax rates in the group (See the proof in appendix).*

Corollary 80.3 *In the group of small countries, the two countries bordering the large countries set the highest tax rate. The lowest tax rate appears at the geographical middle of the group. The tax rates increase from the middle to each ends of the group (Shown in the Proof of Proposition 80.2).*

The K-country model give two direct implications. Firstly, the size is significant. The big countries can afford to set higher tax rate because they have bigger demand, while smaller countries have to lower their tax to attract foreign demand. That is partly why the international tax havens are always smaller economies, for instance, the Cayman islands.

Secondly, the big neighbors are positively related to local tax rate. From Proposition 80.3, when there are big neighbors, a country tends to levy higher tax than other countries in its league. Surrounded by bigger countries means more cross-border demand from the outside world. On the contrary, the economies surrounded by small countries have to push tax lower to keep a decent fiscal income.

If we relax the unified country sizes in k-country models, we can have an interesting numerical example directly from Proposition 80.2. China, Myanmar, Indonesia and Philippine are geographically on one curve neighboring each other. We arbitrarily define the size of above four countries as L_0, L_1, L_2, L_3, where $L_0 = 10a, L_1 = a, L_2 = 2a, L_3 = a$. Here we assume the size of China is much bigger than the rest, and Indonesia is twice as big as that of Myanmar. The equilibrium tax rate will be $p_1 = \frac{4}{3}\gamma a$, $p_2 = \frac{7}{6}\gamma a$. The neighbouring effect dominates the size effect in this case. The huge demand from China may be so big that the smaller economy set higher tax rate than its big neighbor. However, if the size of China is not so big, say, $L_0 = 4a$. The equilibrium changes to $p_1 = \frac{20}{24}\gamma a$, $p_2 = \frac{21}{24}\gamma a$. Indonesia sets higher tax than Myanmar. The size effect dominates the neighbor effect. The bigger country set higher tax rate than the country with big neighbor.

The example also implies that the tax game is dynamic. It changes with the economic performance of the region. When a country grow fast, it may out-pace its neighbors and change the tax distribution of the whole region.

80.4 Hotelling Model and Peripheral Effects

Peripheral effects are the distinguishing difference between Hotelling and Salop model. Hotelling model is a linear world, hence two countries on the ends occur inevitably. The peripheries have only one side open to other countries while the interior ones open in both sides. It brings periphery effects from those two special cases, where inward cross-border demand is limited.

The Hotelling model is similar to Salop but in the peripheries. Consider a linear world, where countries are located on a line. Countries divide the circular world into n adjacent and non-overlapping segments. The segment of $[0, L_0]$ represent the land of country 0, $[L_0, L_1]$ represent the land of country 1, $[L_i, L_{i+1}]$ represent the land of country i, and so on and so forth. The countries at the two ends of the line are called peripheral countries, while the rest are defined as interior countries. Each interior country has two neighbors, one to each side, i.e., country i is neighboring country $i+1$ and country $i-1$. The peripheral countries are country 0 and country $n-1$. Country 0 is neighboring only country 1, while country $n-1$ is neighboring country $n-2$ only.

The cross-border shopping demand is

$$C_i(p_i - p_{i+1}) = \min\{(p_i - p_{i+1})\,|\gamma\ , A_i\}. \tag{80.6}$$

The tax revenue in the interior countries are

$$\pi_i(p_0, \ldots, p_{n-1}) = \left(L_i + \tfrac{1}{\gamma}(p_{i-1} + p_{i+1} - 2p_i)\right) \times p_i, \tag{80.7}$$

where $i = 1, 3, \ldots, n-2$.

Tax revenue for peripheral countries is

$$\begin{aligned} \pi_0(p_0, \ldots, p_{n-1}) &= \left(L_0 + \tfrac{1}{\gamma}(p_1 - p_0)\right) \cdot p_0 \\ \pi_{n-1}(p_0, \ldots, p_{n-1}) &= \left(L_{n-1} + \tfrac{1}{\gamma}(p_{n-2} - p_{n-1})\right) \cdot p_{n-1} \end{aligned} \tag{80.8}$$

Equations (80.7) and (80.8) are strictly concave functions in tax rates. Thus the FOC indicates best response.

$$p_i = \tfrac{1}{4}(\gamma L_i + p_{i-1} + p_{i+1}), \tag{80.9}$$

where $i = 1, 2, \ldots n-2$.

From Eq. (80.8), the interior countries' best response functions are

$$p_0 = \frac{1}{2}(\gamma L_0 + p_1), \tag{80.10}$$

$$p_{n-1} = \frac{1}{2}(\gamma L_{n-1} + p_{n-2}). \tag{80.11}$$

From Eqs. (80.8) and (80.9), a linear system of the best response function can be given:

$$\overline{A} = \overline{B} \cdot \overline{P}, \tag{80.12}$$

where $\overline{A} = \frac{1}{4}\gamma \begin{bmatrix} L_0 \\ L_1 \\ \vdots \\ L_{n-1} \end{bmatrix}$ and $\overline{B} = \begin{bmatrix} \frac{1}{2} & -\frac{1}{4} & 0 & \cdots & 0 \\ -\frac{1}{4} & 1 & -\frac{1}{4} & \cdots & 0 \\ 0 & -\frac{1}{4} & 1 & -\frac{1}{4} & \vdots \\ 0 & \vdots & \vdots & \ddots & 0 \\ 0 & 0 & \cdots & -\frac{1}{4} & \frac{1}{2} \end{bmatrix} = \begin{bmatrix} b_0 & c_0 & & & 0 \\ a_1 & b_1 & c_1 & & \\ & \vdots & \ddots & & \vdots \\ & & \cdots & & c_{n-2} \\ 0 & & \cdots & a_{n-1} & b_{n-1} \end{bmatrix}$.

The tax rates index is denoted by $\bar{P}$. Equilibrium tax rates are given by $\overline{P}$. $P^* = \overline{B}^{-1} \cdot \overline{A}$. $\overline{B}$ is different from B given in Sect. 80.3 only on the first and last row. $\overline{B}$ is an invertible tridiangnal matrix, thus P^* presents a unique Nash equilibrium to this linear system. Hence Proposition 80.4.

Proposition 80.4 (Please find the proof in appendix.) *There always exists a unique tax equilibrium in the Hotelling tax competition. Equilibrium tax rates are given by following difference equation:*

$$\begin{cases} p_{n-1} = \frac{L_{n-1} + \frac{1}{4} y_{n-2}}{1 - \frac{1}{4}\beta_{n-2}} \\ p_i = y_i - \beta_i \cdot p_{i+1}, \end{cases}$$

where $\begin{cases} y_1 = 2L_1 \\ y_i = \frac{L_i + \frac{y_{i-1}}{4}}{1 - \frac{1}{4}\beta_{i-1}} \end{cases}$*, and* $\beta_i = -\frac{(2+\sqrt{3})^{i-1} + (2-\sqrt{3})^{i-1}}{(2+\sqrt{3})^{i} + (2-\sqrt{3})^{i}}$.

Proposition 80.4 gives analytical solution to any Hotelling tax game. It suggests that with the three effects' coexistence, there is no simple tax distribution in the tax game with more than 3 countries. However, it does suggest that size, neighbor and peripheral effect have positive relation with tax rate. Numerical example may help us understand Proposition 80.4.

We take possible tax game in Asia as an example. Thailand, Hong Kong and Taiwan are located on a curve neighboring each other, with land size L_0, L_1, L_2 respectively. We arbitrarily assume that they are of the same size, where $L_0 = L_1 = L_2 = a$. Apply Proposition 80.4, we have $p_0 = p_2 = \frac{5}{6}\gamma a$, while $p_1 = \frac{2}{3}\gamma a$. The peripheral effect significantly pushes up the tax rate for the countries on the geographic ends.

When the effects are effective together, the picture may be blurred. Instead of Hong Kong, if we have China in the middle as interior country, the tax equilibrium changes dramatically. Now the region consists Thailand, China and Taiwan. Considering the huge size of China, we let $L_1 = 4a$. The tax equilibrium is now $p_0 = p_2 = \frac{4}{3}\gamma a$, $p_1 = \frac{5}{3}\gamma a$. The size effect dominates the peripheral effect. If we increase the number of participant countries, we can also test the effect of neighbors.

When the peripheral effect exists in the tax game, both size effect and the neighborhood effect still emerge and significantly influence the equilibrium. When they put each impact on the tax distribution, the game becomes more dynamic and interesting.

80.5 Conclusion

The central message of this paper is to describe the impact of cross-border shopping on regional tax rates distribution. The sizes of the countries, the neighbors of the countries and the countries' geographic locations determine the tax distribution. We show that the size effect, neighbor effect and peripheral effect are positively related to tax rates.

We provide a simple general model of a circular world with future potential in this paper. This multi-country model enables geographical size differentiation. Analyses of the game explain the tax mechanism in the international trade context with tax authorities governing national sovereignties in different sizes. By analysing the equilibrium, we realize the impact from cross-border shopping and the geographic features on the regional tax distribution.

The two main findings from the first part of the paper are: country sizes are positively related to the countries' own tax rates; the sizes of the countries' tax rates are positively related to their neighboring countries sizes as well as their own. These findings have been tested by a set of numeric examples. The first one is coherent with existing literature, confirming the circular model's solidity in explaining cross-border shopping. It provides possibility of applying country size differentiation in computing and analysing equilibrium in a model with more than 3 countries. The second finding is new to existing knowledge in the international taxation study: tax rate is influenced by the geographic sizes of the country's neighbors. The tax rates of the neighboring countries are positively related to the subject country's tax rate. Both findings can be reflected in real-world examples, e.g., the European petrol price index.

The second part of the paper shows a Hotelling model of regional tax competition. It facilitates us to study the coexistence and correlation of size effect, neighborhood effect and peripheral effect in one model. We argue that the peripheral effect can dictate tax distribution when country size difference is not big enough.

Appendix

Proof of Proposition 80.2 To analyse the equilibrium, we let

$$Q = B^{-1} = \begin{bmatrix} 1 & -\frac{1}{4} & 0 & \cdots & -\frac{1}{4} \\ -\frac{1}{4} & 1 & -\frac{1}{4} & \cdots & 0 \\ 0 & -\frac{1}{4} & 1 & -\frac{1}{4} & \vdots \\ 0 & \vdots & \vdots & \ddots & 0 \\ -\frac{1}{4} & 0 & \cdots & -\frac{1}{4} & 1 \end{bmatrix}^{-1}.$$

Q is the inverse of B, which is also a symmetric circulant matrix, which is defined by its first row. From Eq. (80.3), the first row of Q is $q_0 = (q_{0,0}, q_{0,1}, q_{0,2}, \ldots q_{0,n-1})$. To ensure $QB = I$, q_0 must solve the following system:

$$q_{0,0} - \tfrac{1}{4}q_{0,1} - \tfrac{1}{4}q_{0,n-1} = 1, \tag{80.13}$$
$$-\tfrac{1}{4}q_{0,j-1} + q_{0,j} - \tfrac{1}{4}q_{0,j+1} = 1, \tag{80.14}$$
$$-\tfrac{1}{4}q_{0,0} - \tfrac{1}{4}q_{0,n-2} + q_{0,n-1} = 1. \tag{80.15}$$

Equation (80.14) is a second order linear difference equation with characteristic roots $\lambda = 2 - \sqrt{3}$ and $\mu = 2 + \sqrt{3}$. Notice that $0 < \lambda < 1 < \mu$. The general solution to Eq. (80.14) is, for some constant a and b:

$$q_{0,j} = a\lambda^j + b\mu^j. \tag{80.16}$$

Substitute Eq. (80.16) into (80.13) and (80.15), we solve for a and b.

$$\begin{array}{l} a = \frac{2}{(1-\lambda^n)\sqrt{3}} \\ b = \frac{2}{(\mu^n-1)\sqrt{3}} \end{array}. \tag{80.17}$$

Notice that $q_{0,j} > 0, \forall j \in N$.

Two properties of Q need to be addressed. First of all, Q is a symmetric circulant matrix, it has a property that $q_{0,j} = q_{0,n-j}$. Secondly, in matrix Q, we can show that in the first row of it, $q_{0,0} > q_{0,1} > q_{0,2} > \cdots > q_{0,\frac{n}{2}}, \quad q_{0,\frac{n}{2}} < q_{0,\frac{n}{2}+1} < q_{0,\frac{n}{2}+2} < \cdots < q_{0,n-1}$ if n is even. It also follows the same logic when n is odd. The intuition is that the elements of q_0 initially decreases from left to the right, and then increase from middle to the right end. Following two lemmas establish these two properties.

Lemma 80.1 *When Q is a symmetric circulant matrix as we defined above, $q_{0,j} = q_{0,n-j}$.*

Lemma 80.2 *When Q is a symmetric circulant matrix as we described above, $q_{0,j} > q_{0,j+1}$, where $j \in [0, n/2 - 1]$ when even, and $j \in [0, (n-1)/2 - 1]$ when odd, $\forall n \geq 3$.*

Lemma 80.3 $S_{h+1} < q_{0,h}, \forall h \in \{0, 1, 2, \ldots, n/2 - 1\}$.

Proposition 80.5 *If $i \Delta j$, then $pi > pj$. If neither $i \Delta j$ nor $j \Delta i$, then $p_i = pj$.*

Proof First consider two countries, i and j, where i is large and j is small. We set this example to extreme, where all $i's$ neighbors are all small countries, while all $j's$ neighbor's are large countries. We define these two countries located exactly the same. The tax rates difference between these two countries cannot be higher than this example, where $\sharp m(i) = 1$ and $\sharp m(j) = 0$. The tax rate difference is:

$$p_i - p_j = (q_{0,i} - S_{i+1})(L_L - L_S) > 0.$$

Notice that here $q_{0,i} = q_{0,j}$, as both countries are located identically.

From Lemma 80.3, $q_{0,i} - S_{i+1} > 0$. And $L_L - L_S > 0$ is defined. So $\sharp mi(1) = 1$ and $\sharp mj(1) = 0$, $p_i > p_j$. As we assumed, $j's$ neighbors are all large countries, and this is the extreme case of all possibilities, where the tax rates difference is the lowest when j is small and i is big. This property implies that large countries always set higher tax rates than small countries.

Secondly, we can assume two big countries i and j, where country i has one big neighbor, while j has none. Again, we make this example extreme, where all countries that are 2 countries away from i are all small, and those 2 countries from j are all large. Again, we let these two countries located at the same place. Now the tax rates difference is:

$$\begin{aligned} p_i - p_j &= [(q_{0,i} + q_{0,i+1})L_L + q_{0,i-1}L_S + S_{i+2}L_S] \\ &\quad - [q_{0,j}L_L + (q_{0,j+1} + q_{0,j-1})L_S + S_{j+2}L_L] \\ &= (q_{0,i+1} - S_{i+2})(L_L - L_S) > 0, \\ \Leftrightarrow p_i &> p_j. \end{aligned}$$

Consider the general case $\sharp m^*(i) = \sharp m^*(j) + 1$, and all country $j's$ neighbors who are $m^* + 1$ away are all big countries and country $i's$ neighbors who are $m^* + 1$ away are all small countries. This is an extreme case, where the difference between p_i and p_j is no less than this extreme case. Notice here

$$\begin{aligned} p_i &= q_i L, \;\; p_j = q_j L, \\ p_i - p_j &= q_i L - q_j L \\ &\geq q_{0,m*}(L_L - L_S) + (S_{m*+1}L_S - S_{m*+1}L_L) \\ &= (q_{0,m} - S_{m+1})(L_L - L_S) > 0, \\ \Leftrightarrow p_i - p_j &> 0. \end{aligned}$$

As we argued before, no other instance will result in greater difference than this extreme case. This general case shows us the first part of this proposition.

If neither $i \Delta j$ nor $j \Delta i$, the two countries have the same size and exactly the same neighborhoods. Those two countries, with identical geographic characteristics and identical international taxation environment, set the same tax rate.

References

1. Bhaskar V, To T (2003) Oligopsony and the distribution of wages. Eur Econ Rev 47(2):371–399
2. Cremer H, Gahvari F (2000) Tax evasion, fiscal competition and economic integration. Eur Econ Rev 44(9):1633–1657
3. Esteller-More A, Solé-Ollé A (2001) Vertical income tax externalities and fiscal interdependence: evidence from the us. Reg Sci Urban Econ 31(2):247–272

4. Kanbur R, Keen M (1993) Tax competition and tax coordination when countries differ in size. Am Econ Rev 83:877–892
5. Liu X, Madden P (2013) Small country may have higher tax rate
6. Nagurney A, Nagurney LS (2015) A game theory model of cybersecurity investments with information asymmetry. NETNOMICS Econ Res Electron Network 16(1–2):127–148
7. Nielsen SB (2001) A simple model of commodity taxation and cross-border shopping. Scand J Econ 103(4):599–623
8. Ohsawa Y (1999) Cross-Border shopping and commodity tax competition among governments. Reg Sci Urban Econ 29:33–51
9. Patrick C (2014) The economic development incentives game: an imperfect information, heterogeneous communities approach. Ann Reg Sci 53(1):137–156
10. Trandel G (1994) Interstate commodity tax differentiatials and the distribution of residents. J Public Econ 53:435–457
11. Wang YQ (1999) Commodity taxes under fiscal competition: stackelberg equilibrium and optimality. Am Econ Rev 89(4):974–981
12. Zhuang J, Saxton GD, Wu H (2014) Publicity vs impact in nonprofit disclosures and donor preferences: a sequential game with one nonprofit organization and n donors. Ann Oper Res 221(1):469–491

Chapter 81
Techno-Economical Advances for Maintenance Management of Concentrated Solar Power Plants

Jesús María Pinar Pérez, Fausto Pedro García Márquez and Mayorkinos Papaelias

Abstract Concentrated solar power (CSP) capacity has experienced strong growth. Nowadays, the CSP industry is focused on decreasing the operation and maintenance (O&M) costs and to set appropriate non-destructive testing techniques for inspection of critical components of the plants. The implementation of condition monitoring systems will reduce O&M costs and energy losses. The main objective of this paper is to present a review of the condition monitoring techniques for solar absorber tubes, insulated pipes and storage tanks of parabolic trough and linear Fresner receiver plants.

Keywords Concentrated solar power · Condition monitoring · Non-destructive testing · Maintenance management

81.1 Introduction

The growing electricity demand, the effects of climate change and the depletion of fossil fuels increase the need for clean, stable and affordable renewable energy sources. The electricity generated by renewable energies has grown over the last few years, and CSP appears as a promising renewable source. CSP technology has currently a small share of the total renewables energies capacity worldwide [19]. However, forecast studies indicate that CSP has increased the experienced a growth in installed capacity of more than 1000 % since 2006 (see Fig. 81.1) [19]. The levelized

J.M.P. Pérez
CUNEF-Ingenium Group, Cunef, Madrid, Spain

F.P.G. Márquez (✉)
Ingenium Research Group, University of Castilla-La Mancha, Ciudad Real, Spain
e-mail: FaustoPedro.Garcia@uclm.es

M. Papaelias
School of Metallurgy and Materials, The University of Birmingham, Birmingham, UK

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_81

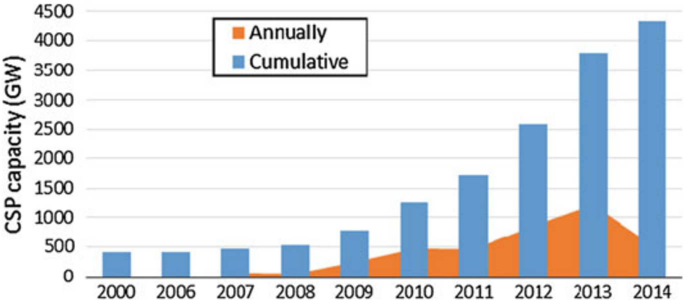


Fig. 81.1 Worldwide CSP installed capacity (data from [19])

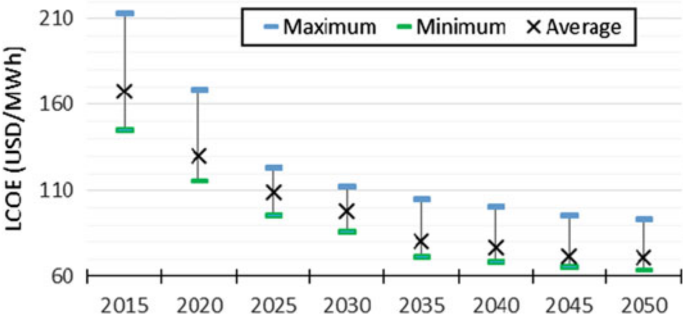


Fig. 81.2 Projections of LCOE for new-built CSP plants [18]

cost of electricity (LCOE) is defined as the cost of the electricity generation. It is used to compare the cost of generation among different technologies. The LCOE in 2014 for onshore wind energy is from 60 to 95 USD/MWh, and hydro energy is from 40 to 120 USD/MWh [17]. The LCOE for CSP is from 150 to 220 USD/MWh [17], and it reveals that CSP energy is more expensive than wind or hydro energy due to the maturity of these energy technologies. Figure 81.2 shows the projections of the international energy agency for the LCOE of new-built CSP plants. LCOE will drop in the forthcoming years very fast and then stabilise at 70 USD/MWh in 2050.

The operating costs of CSP plants are low compared to fossil fuel-fired power plants, but are still significant. O&M costs for CSP plants are around 0.04 USD/kWh [16]. The replacement of receivers and mirrors must be often carried out due to failures or damages contributing significantly to the overall maintenance costs. For example, the replacement of a solar absorber tube is around 1000 €, i.e., € 0.5 Million per annum for a 50 MW CSP plant [30].

CSP plant operators rely more corrective maintenance than preventive maintenance which leads to decreased efficiency of maintenance activities. The automation of maintenance tasks and an accurate real-time diagnostics will contribute to the reduction O&M costs, as well as improvement of performance [16]. The reliability, availability, maintainability and safety (RAMS) of CSP plants must be improved using efficient and cost-effective techniques of inspection. This paper focuses on the review of the inspection techniques.

81.2 Concentrated Solar Plants

CSP plants employ mirrors to concentrate a large amount of solar rays on a solar receiver where a working fluid is flowing. The working fluid (e.g. oil, molten salts, or air) is heated and then fed to a heat exchanger in order to generate steam. CSP plants working with steam do not require a heat exchanger since the steam is directly driven to the steam turbine generating the electricity. Thermal storage tanks are usually used between the solar field and the heat exchanger of the steam turbine. Figure 81.3 shows a scheme of a typical parabolic trough plant.

Nowadays, there are four different available and implemented of CSP technologies: parabolic trough, linear Fresner reflector, parabolic dish system and solar power towers [50]. Table 81.1 shows CSP technologies depending on the type of focus (line or point focus) and receiver type (fixed or mobile receivers). Solar power towers employ volumetric solar receivers which are difficult to inspect with the current available techniques. Parabolic trough system is the technology most implemented [27] and employs absorber tubes, as receivers, with a complex morphology to inspect (Fig. 81.4).

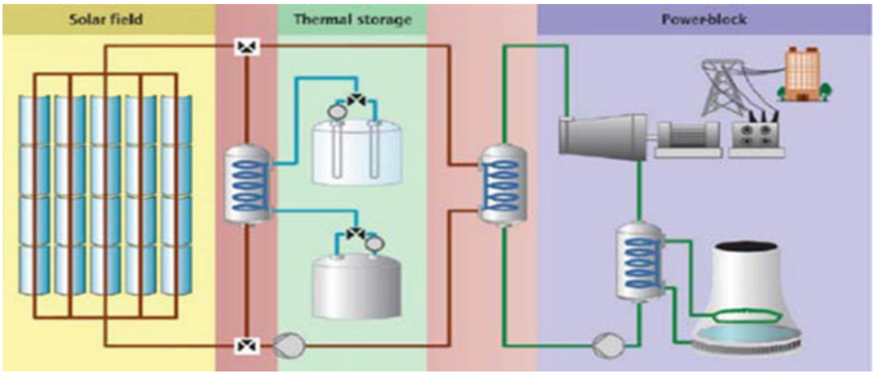
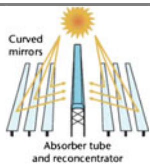
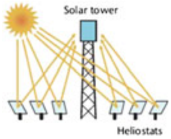
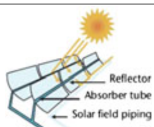


Fig. 81.3 Scheme of a parabolic trough plant [26]

Table 81.1 Main CSP technologies [18]

Receiver type	Focus type	
	Line focus: Collectors track the sun along a single axis and focus irradiance on a linear receiver. This makes tracking the sun simpler	**Point focus**: Collectors track the sun along two axes and focus irradiance at a single point receiver. This allows for good receiver efficiency at higher temperatures
Fixed: Fixed receivers are stationary devices that remain independent of the plant's focusing device. This eases the transport of collected heat to the power block	 ***Linear Fresnel reflectors***	 ***Towers***
Mobile: Mobile receivers move together with the focusing device. In both line focus and point focus designs, mobile receivers collect more energy	 ***Parabolic troughs***	 ***Parabolic dishes***

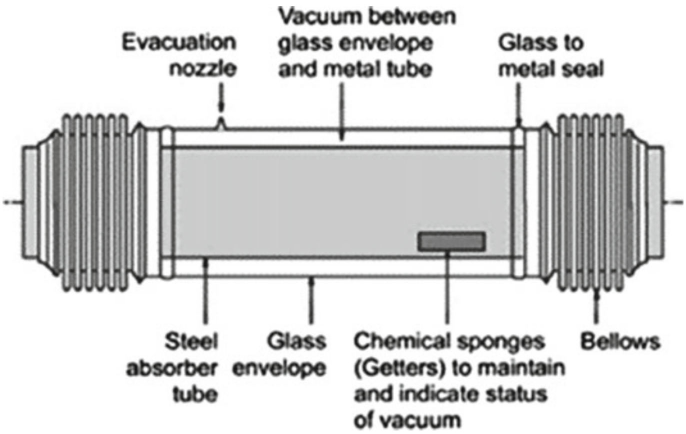


Fig. 81.4 Absorber tube [26]

81.3 Maintenance Theory

Maintenance is necessary to ensure the good operation of the components. The basic objectives of the maintenance activity are to deploy the minimum resources required to ensure that components perform their intended functions properly, to ensure system reliability and to recover from breakdowns [21].

81.3.1 Corrective, Scheduled and Condition Based Maintenance

Classical theory sees maintenance as either corrective or preventive. The former (also known as unscheduled or failure based maintenance) is carried out when any component of the CSP plant break down and when faults are detected or failures occur in any of the components. Immediate refurbishment or replacement of parts may be necessary [2] and unscheduled downtime will result. Corrective maintenance is therefore the most expensive of strategies and CSP plant operators will hope to resort to it as little as possible. By contrast, the objective behind preventive maintenance (PM) is to either repair or replace components before they fail [2]. This has most straightforwardly been achieved by scheduled maintenance, also known as time based (or planned) maintenance and involving repair or replacement at regular time intervals as recommended by the supplier and regardless of condition. Scheduled maintenance tasks in CSP such as the cleaning of mirrors.

But reducing failures in this way comes at the cost of completing maintenance tasks more frequently than absolutely necessary and not exhausting the full life of the various components already in-service. An alternative is to mitigate against major component failure and system breakdown with condition based maintenance (CBM) in which continuous monitoring and inspection techniques are employed to detect incipient faults early, and to determine any necessary maintenance tasks ahead of failure [33]. This involves acquisition, processing, analysis and interpretation of data and selection of optimal maintenance actions [45] and is achieved using condition monitoring systems [10]. CBM has been shown to minimise the costs of maintenance, improve operational safety, and reduce the quantity and severity of in-service system failures.

81.3.2 Reliability Centred Maintenance

Reliability centred maintenance (RCM) has been formally defined as “a process used to determine what must be done to ensure that any physical asset continues to do whatever its users want it to do in its present operating context” [24]. It involves maintaining system functions, identifying failure modes, prioritizing functions, identifying PM requirements and selecting the most appropriate maintenance tasks [43] with the objective of managing system failure risk effectively [22]; operational and maintenance policies are optimized such that the overall maintenance task is reduced [2]. RCM has been recognized and accepted in many industrial fields, such as steel plants, railway networks, ship maintenance and other industries.

81.4 Inspection Techniques

There are many components and parts of a CSP plant to be inspected. Some of these components must to be inspected without insulation or working fluids, therefore, outages must be realized to carry out these inspections. Outages are related with production losses but inspections are necessary to ensure the good operation of the plant. This section presents the characteristics of each inspection technique available for CSP parabolic troughs and linear Fresnel reflectors. Table 81.2 presents a summary of the characteristics of each technique explained next and the related references from literature.

(1) Visual Inspection

The personal of maintenance carry out the visual inspection (VI) of the structural components of the CSP plant frequently. Large visible effects on surfaces, damaged insulation, working fluid leaks, missing components or dust on mirrors are some of the detectable damages by this technique. Not all the components can be inspected in the operation of the plant. The visual inspection of insulated components or internal surfaces of the tanks must be carry out during outages due to the necessary removal of the insulation from pipes or the empty of storage tanks [30]. This technique can be automated by remotely controlled vehicles with video cameras, i.e. automated vision inspections (AVI). Planned outages are necessary to realize the visual inspection of the internal surface of pipes by robots with video cameras, i.e. the pipe crawling inspection robots (PCIR) [39, 49].

(2) Liquid Penetrant Inspection

Liquid penetrant inspection (LPI) is realized by certified inspection personnel to detect surface-breaking defects visually. A special dyes are spread over the surface to inspect such as welds. Then, a developer is applied showing a visible indication of the defect. Outages are necessary for the application of this technique to insulated pipes or internal surfaces of empty tanks [13].

(3) Magnetic Particle Inspection

Magnetic particle inspection (MPI) consists on to magnetise the surface area to inspect that it is previously sprayed with ferrous particles. In the case of a breaking-surface, the magnetic flux make the alignment of the ferrous particles sprayed before, indicating the location of the damage to the maintenance personnel. MPI is employed in the inspections of ferrous components such as ferrous pipes of the secondary coolant system, cold storage tanks or welds. This technique is a visual inspection

Table 81.2 Characteristics of each technique and references from literature (1)

Technique	Used in	Carry out by	Detection capability	Outages	References
Visual VI	Structural components	Personnel	Large visible effects on surfaces, damaged insulation, leaks, missing components, dust on mirrors	Neccesary for insulated components or internal surfaces of the tanks	[30]
AV	Structural components	Remotely controlled vehicles	Large visible effects on surfaces, damaged on surfaces, damaged insulation, leaks, missing components, dust on mirrors	Neccesary for insulated components	[39]
PCIR	Internal pipes	Robots	only for visible defects	Yes	[49]
LPI	Welds	Certified inspection personnel	Small surface-breaking defects such as fatigue cracks and corrosion pits of the tanks	Necessary for insulated components or internal surfaces	[13]
MPI	Ferrous pipes (secondary coolant system), cold storage tanks, welds	Strong portable electromagnet device	Small surface-breaking defects, very near-surface cracks and corrosion pits	Necessary for insulated components internal surfaces of the tanks	[13]
MFL	Insulated ferrous pipe-lines, heat exchanger tubes and cold storage tanks	Hall-effect sensor/ bulky equipment	Pitting, general corrosion and cracks	Not for CMFL	[1, 8, 41, 48]
ECT	Pipelines, absorber tubes	Eddy current sensor, robotic crawlers	Surface and near-surface defects (cracks and pitting corrosion), general corrosion, microstructural changes	Without insulation	[11, 12, 38, 44]

technique not applicable for components manufactured from austenitic stainless steel grades [13].

(4) Magnetic Flux Leakage Inspection

Magnetic Flux Leakage (MFL) inspection is an electromagnetic technique of Non-Destructive Testing method to detect pitting, general corrosion and cracks. It is based on magnetising the ferrous component to inspect with a powerful magnetic field. If the component has not defects the magnetic flux lines will remain undisturbed. Nevertheless, where there is a defect the magnetic flux will leaks from the component. This technique employs a MFL testing device based on Hall-effect and capable to record the magnetic flux leakages. MFL is used in insulated ferrous pipelines, heat exchanger tubes or cold storage tanks. The removal of insulations is necessary to apply MFL [1, 8, 41].

The potential of Pulsed Magnetic Flux Leakage (PMFL) technique has been demonstrated in [48] to find damages on insulated steel pipes.

(5) Eddy Current Testing

Eddy Current (EC) testing employs electromagnetic induction to detect discontinuities in conductive materials. Eddy current is based on the changing magnetic field generated in a coil when alternating current is applied. If the coil is brought near of the surface of a conductor, the magnetic field of this excited coil generate "eddy" current within the conductor. Additionally, the Eddy current induced in the conductor generate their own magnetic field (Lenz's Law) opposed to the magnetic field generated by the excited coil. This secondary magnetic field will fluctuate when surface or near-surface defects are presented in the component varying the impedance of the sensing coil. The identification and definition of damages can be evaluated by these impedance changes [11, 12].

Pulsed EC is able to detect pitting corrosion or cracks in pipelines when the insulation is removed and microstructural changes of both the cermet coating and substrate of the solar absorber tube [38, 44].

(6) Alternating Current Field Measurement

Alternating Current Field Measurement (ACFM) is useful for the detection and identification of surface breaking defects such as corrosion and cracks. This technique is similar to EC, but ACFM take into account the AC field changes generated around the defects instead of the impedance in EC. Sensing coils orientated are able to detect both depth and length of the surface defect [47]. ACFM is used to detect and identify fatigue cracks in welds. Pipelines and the outer area of absorber tubes can be inspected with this technique. The resolution of ACFM is poor and increase dramatically when the insulation is removed [31, 32].

(7) Radiographic Inspection

Radiographic imaging of structural components using X-rays provides useful information regarding the structural condition of the component being inspected. Radiographic imaging depends "on the different level of absorption of X-ray photons as they pass through a materia" [37]. A transportable radiographic system can be implemented in CSP such as in wind farms, where it was demonstrated as "a solution to find defects and reduce the cost of inspection" [9]. Nowadays, radiographic digital inspection is available using digital records [36].

Radiographic inspection can be carry out in operation without the removal of insulations. This technique allows to detect corrosion and weld defects in tubing, piping and storage tanks [35, 51]. A statistical guide of the condition of the plant can be developed using radiographic inspection [30].

(8) Ultrasonic Testing

Ultrasonic testing (UT) is generally employed for the detection and qualitative assessment of surface and subsurface structural defects [5, 21]. Ultrasonic wave propagation characteristics allow estimation of the location and type of defect detected, thus providing a reliable method of determining the material properties of the components. UT is based on piezoelectric transducers ultrasonically coupled on the surface of the component to be inspected [28, 29]. Cracks and corrosion in pipelines and storage tanks can be detected with this technique if the insulation is removed previously. UT can be used for the inspection of supporting structures [30].

(9) Long Range Ultrasonic Testing

Long Range Ultrasonic Testing (LRUT) is carried out by piezoelectric transducers fitted around a pipe using and inflatable ring within a small pipe length where the insulation has been removed [30]. LRUT is used to evaluate long sections of welded pipes and tubes detecting corrosion and cracks [4, 25, 40, 42]. Absorber tubes can be evaluated with this technique. LRUT is carry out during outages unless pipes or tubes are below 100 °C [23, 30].

(10) Electromagnetic Acoustic Transducers

Electromagnetic Acoustic Transducers (EMATs) is a UT technique employing non-contact electromagnetic sensors capable of generating and receiving ultrasonic waves. EMAT is useful for automated inspections and it is able to work under high temperature conditions or dry [3, 6, 7, 14, 15]. Outages of CSP plant are not necessary to apply this technique. It is easy to produce specific waves and modes such as Rayleigh waves used in absorber tubes and insulated pipes inspections [30].

(11) Infrared Thermography

Infrared (IR) thermography inspection is carry out by expensive infrared cameras. This technique is used to detect damaged insulation, leaks and heat losses in the plant [20], but it is difficult to detect structural defects. Absorber tubes can be inspected with this technique providing an idea of the overall condition of the plant [34].

(12) Acoustic Emission

Rapid release of strain energy takes place and elastic waves are generated when the structure of a metal is altered, and this can be analyzed by acoustic emissions (AE) [23]. Very sensitive piezoelectric sensors are employed by this technique. AE is able to detect and monitor defects such as corrosion, cracking and leaks providing qualitative information (presence and location of the defect) to the maintenance stuff. The structural health monitoring of storage tanks can be achieved by AE. Corrosion debris, corrosion detection and crack initiation and propagation can be detected in pipes or tubes of the CSP plant by AE [30].

Table 81.3 Characteristics of each technique and references from literature (2)

Technique	Used in	Carry out by	Detection capability	Outages	References
ACFM	Welds, pipelines and the outer area of absorber tubes	Pigs, robotic crawlers pitting corrosion cracks and fatigue	Surface-breaking defects including removed	Better resolution if insulation is	[31, 32, 47]
Radiography	Tubing, piping and storage tanks	Transportable radiographic system	Internal and surface defects associated with corrosion and weld inclusions	No	[9, 35, 37, 51]
UT	Pipelines and storage tanks	Piezoelectric transducers	Internal and surface defects including fatigue cracks and corrosion	Removal of insulation	[5, 8, 21, 28, 29]
LRUT	Piping, tubing, absorber tubes	Ring of piezoelectric transducers	Large hidden and surface breaking defects. Relatively severe corrosion and transverse cracks	No if $<100\,°C$/ requires removal of insulation only in the area of installation	[4, 23, 25, 40, 42]
EMATs	Absorber tubes and insulated pipes	Piezoelectric transducers	Surface and hidden defects including corrosion and fatigue cracks	No	[3, 6, 7, 14, 15, 46]
IR	In general	IR cameras	Heat losses and leak detection	No	[20, 34]
AE	Storage tanks, pipes and tubes	Very sensitive piezoelectric sensors	Corrosion, cracking, leaks	No	[20, 23, 30, 33]
Elec. Effects	Elect. Motors of the mirrors structure	Electrical sensors	Electrical or mechanical damages	No	

(13) Electrical Effects

For the optimal performance of the plant, the rays of the sun reflected by the mirror must be precisely focus on the receiver. Electrical motors used for the alignment of mirrors or sun sensors can fail, for this reason the continuous monitoring is performed using voltage and current measures [23] (Table 81.3).

81.5 Conclusions

The CSP industry is focused on decreasing LCOE through the reduction of O&M costs. In order to achieve this, it is necessary to set adequate techniques for the effective inspection of critical components and infrastructure. The implementation of effective condition monitoring systems will reduce O&M costs and energy losses. A review of the main condition monitoring techniques for some components of Parabolic Trough and Linear Fresner receivers Plants has been carried out, specifically, components such as solar absorber tubes, insulated pipes and storage tanks.

References

1. Afzal M, Udpa S (2002) Advanced signal processing of magnetic flux leakage data obtained from seamless gas pipeline. NDT E Int 35(7):449–457
2. Ben-Daya MS, Ait-Kadi D et al (2009) Handbook of maintenance management and engineering, vol 7. Springer, Berlin
3. Bobbin J (1979) EMAT: high-temperature probe electromagnetic acoustic transducer. In: Materials evaluation, vol 37, Amer Sco, Non-Destructive Test 1711 Arlingate Lane PO Box 28518, Columbus, 43228-0518, pp 28–28
4. Cawley P, Lowe M et al (2003) Practical long range guided wave inspection-applications to pipes and rail. Mater Eval 61(1):66–74
5. Deshpande V, Modak J (2002) Application of rcm for safety considerations in a steel plant. Reliab Eng Syst Saf 78(3):325–334
6. Dixon S, Palmer S (2004) Wideband low frequency generation and detection of lamb and rayleigh waves using electromagnetic acoustic transducers (EMATS). Ultrasonics 42(10):1129–1136
7. Dixon S, Edwards C et al (1995) Using emats to measure the wall thickness of hot galvanizing kettles. Insight 37(5):368–370
8. Drury J, Marino A (2000) A comparison of the magnetic flux leakage and ultrasonic methods in the detection and measurement of corrosion pitting in ferrous plate and pipe. In: Proceedings of the 15th world conference on non-destructive testing
9. Fantidis J, Potolias C, Bandekas D (2011) Wind turbine blade nondestructive testing with a transportable radiography system. Science and Technology of Nuclear Installations 2011
10. García FP, Pedregal DJ, Roberts C (2010) Time series methods applied to failure prediction and detection. Reliab Eng Syst Saf 95(6):698–703
11. García-Martín J, Gómez-Gil J, Vázquez-Sánchez E (2011) Non-destructive techniques based on eddy current testing. Sensors 11(3):2525–2565
12. Hagemaier DJ (1990) Fundamentals of eddy current testing. American Society for Nondestructive Testing, Columbus. ISBN: 0-931403-90-1
13. Halmshaw R (1989) Introduction to non-destructive testing. Non-destructive testing, pp 1–72
14. Hirao M, Ogi H (1999) An sh-wave emat technique for gas pipeline inspection. NDT E Int 32(3):127–132
15. Hirao M, Ogi H (2003) EMATs for science and industry. Kluwer Academic Publishers, Berlin
16. International Renewable Energy Agency (2012) Concentrating solar power
17. International Renewable Energy Agency (2014) Renewable power generation costs in 2014
18. International Energy Agency (IEA) (2014) Technology roadmap: Solar thermal electricity
19. International Renewable Energy Agency (2015) Renewable energy capacity statistics 2015
20. Jin GX, Xu D et al (2009) Application of infrared thermographic technique in detecting the thermal loss of petrochemical thermal equipment. Infrared Technol 11:014

21. Knezevic J (1993) Reliability, maintainability, and supportability: a probabilistic approach. McGraw-Hill Companies, New York
22. Márquez FPG, Pedregal DJ (2007) Applied RCM2 algorithms based on statistical methods. Int J Autom Comput 4(2):109–116
23. Márquez FPG, Tobias AM et al (2012) Condition monitoring of wind turbines: techniques and methods. Renew Energy 46:169–178
24. Moubray J (1997) Reliability centered maintenance. Industrial Press, New York
25. Mu J, Zhang L, Rose J (2007) Defect circumferential sizing by using long range ultrasonic guided wave focusing techniques in pipe. Nondestruct Test Eval 22(4):239–253
26. Müller-Steinhagen H, Trieb F (2004) Concentrating solar power. Rev Technol Ingenia Inf QR Acad Eng 18:43–50
27. NREL (2016) Csp projects database. http://www.nrel.gov/csp/solarpaces
28. Papadakis EP (1976) Ultrasonic velocity and attenuation: measurement methods with scientific and industrial applications. Phys Acoust 12:277–374
29. Palanichamy P, Joseph A et al (1995) Ultrasonic velocity measurements for estimation of grain size in austenitic stainless steel. NDT E Int 28(3):179–185
30. Papaelias M, Cheng L et al (2016) Inspection and structural health monitoring techniques for concentrated solar power plants. Renew Energy 85:1178–1191
31. Papaelias MP, Roberts C, Davis C (2008) A review on non-destructive evaluation of rails: state-of-the-art and future development. Proc Inst Mech Eng Part F J Rail rapid transit 222(4):367–384
32. Papaelias MP, Lugg M et al (2009) High-speed inspection of rails using acfm techniques. NDT E Int 42(4):328–335
33. Pedregal DJ, García FP, Roberts C (2009) An algorithmic approach for maintenance management based on advanced state space systems and harmonic regressions. Ann Oper Res 166(1):109–124
34. Pfänder M, Lüpfert E, Pistor P (2007) Infrared temperature measurements on solar trough absorber tubes. Sol Energy 81(5):629–635
35. Pincu R (2008) Digital radiography and its advantages in field NDT inspections today. In: Proceedings of the 17th world conference on non-destructive testing, pp 25–28
36. Radiography FI (2005) Filmfree industrial radiography. Filmfree FP6 Project
37. Raišutis R, Jasiūnienė E et al (2008) The review of non-destructive testing techniques suitable for inspection of the wind turbine blades. Ultragarsas (ultrasound) 63(1):26–30
38. Robers M, Scottini R (2002) Pulsed eddy current in corrosion detection. In: Proceedings of the 8th ECNDT
39. Roman HT, Pellegrino B, Sigrist WR (1993) Pipe crawling inspection robots: an overview. IEEE Trans Energy Convers 8(3):576–583
40. Rose J, Ditri J et al (1992) A guided wave inspection technique for nuclear steam generator tubing. In: Proceedings of the 13th world conference of non-destructive testing, vol 92, pp 191–195
41. Saha S, Mukhopadhyay S et al (2010) Empirical structure for characterizing metal loss defects from radial magnetic flux leakage signal. NDT E Int 43(6):507–512
42. Silk M, Bainton K (1979) The propagation in metal tubing of ultrasonic wave modes equivalent to lamb waves. Ultrasonics 17(1):11–19
43. Smith A (1993) Reliability centred maintenance. Mcgraw-hill, New York, p 1993
44. Stalenhoef J, De Raad J (2000) MFL and pec tools for plant inspection. Insight 42(2):74–77
45. Steven B, Campbell J et al (2001) Maintenance excellence, optimizing equipment life-cycle decisions. Campbell, JD, Jardine, AK, Dekker, WM (Eds) pp 43–44
46. Thompson RB (1990) Physical principles of measurements with EMAT transducers. Phys Acoust 19:157–200
47. Topp D (2005) Recent developments and applications of the acfm inspection method and ASCM stress measurement method. Non-Destructive Test Aust 42(5):143
48. Wang Y, Wang X, Ding K (2009) Width quantification of corrosive defect on pipeline based on pulsed magnetic flux leakage. J Test Meas Technol 5:005

49. Zhang Y, Yan G (2007) In-pipe inspection robot with active pipe-diameter adaptability and automatic tractive force adjusting. Mech Mach Theory 42(12):1618–1631
50. Zhang H, Baeyens J et al (2013) Concentrated solar power plants: review and design methodology. Renew Sustain Energy Rev 22:466–481
51. Zscherpel U, Onel Y, Ewert U (2001) New concepts for corrosion inspection of pipelines by digital industrial radiology (IDR). Insight-Northampton-Including European. Issues 43(2): 97–101

Chapter 82
A Review of Investment, Financing and Policies Support Mechanisms for Renewable Energy Development

Yanfei Deng and Wei Guo

Abstract Fossil fuels draw on finite resources, which eventually dwindle, and become too expensive or too environmentally damaging to retrieve. However, renewable sources (RE) represent an effective alternative to fossil fuels for preventing resources depletion and for reducing air pollution. In this context, promoting RE for further development has become an important issue and the diffusion of RE requires huge investment and financing. Investment and financing are becoming crucial agenda for RE development. Meanwhile, renewable growth in recent years have been driven by government-supported programs through policy mechanisms which are playing a very important role in promoting the RE development. This paper reviews the research status of investment and financing for RE development as well as three main support mechanisms employed by governments to finance renewable energy development programs, namely feed-in-tariffs, renewable portfolio standards and tax incentives. Also, the problems of RE development are discussed and it indicates that it is imperative to explore the innovative financing modes as well as investment subsidies, and further study the optimal combination of FIT and RPS and policies incentives.

Keywords Investment · Financing · Renewable energy · Policies support mechanisms

82.1 Introduction

RE is a core alternative energy that can respond to the depletion of fossil fuel, because it is more environment-friendly and sustainable than fossil fuel. The RE possess the merits of non-pollution, sustainability, utilization and development of

Y. Deng (✉)
College of Management, Southwest University for Nationalities, Chengdu 610041, People's Republic of China
e-mail: dengyanfei921@163.com

W. Guo
School of Economics, Xihua University, Chengdu 610039, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_82

RE have become an important topic of world energy demand. In recent years, many countries put an emphasis on the development and deployment of RE to cope with the global environmental crisis such as depletion of fossil energy, climate convention to control emissions of greenhouse gases [21]. Seeking to satisfy the growing energy needs and reduce green-house gas emissions, it is important to use more RE. However, wider consumption of RE is highly related to investment and financing [4]. From the point of view of investment and financing of RE in the international experience, the establishment of a diversified investment and financing system, a set of related policies supporting, is the appropriate way to promote the development of RE. The large sized application of RE, not only need the corresponding investment and financing level, but also require the support mechanisms to finance RE development. To some extent, governments can make a big role of supporting RE. Seeking to increase the use of renewable energy at more rapid rates, governments are implementing various support policies. Therefore, the government should play the role of guiding and encouraging investors, through policies support mechanisms to promote the internalization of external cost of RE, creating a relatively fair policy environment. The analysis of the literature and some interviews with relevant stakeholders have suggested that the effectiveness of renewable energy policies depends on a large set of policy attributes, which include a combination of the right policy signals, incentive levels [34]. Policies to increase the use of RE are widely used internationally and in the recent decade feed-in tariffs (FIT) are among the most commonly used in European countries [5]. Renewable portfolio standards and mandates to invest in energy efficiency are increasingly popular policy tools to combat climate change and dependence on fossil fuels [32]. Within the last few decades, renewable portfolio standards (RPS) have become one of the most commonly adopted climate change policy tools among the states [14]. Additionally, tax incentives are the most widely used governmental instrument [4].

This paper reviews the investment and financing and related support mechanisms. Paper proceeds as follows. First, an overview of the research frame diagram and the technology roadmap is brief introduced. Second, RE investment and financing is reviewed from R&D investment, investment efficiency, financing efficiency, project financing. Third, this paper mainly reviews FIT, RPS, and tax incentives. Finally, a conclusion is drawn.

82.2 Main Research Issues

With the rapid large demand of renewable energy, RE development is facing more and more challenges, particularly in investment and financing. The primary energy demand will increase and guarantee for future generations the supply of energy. Consequently, huge new investment will be necessary into the renewable energy sector in future. According to this, continuous investment in R&D is indispensable for developing advanced technologies, so, the demand for the efficiency of investments has increased. And the article reviews the R&D investment and investment efficiency for RE development. Any ambitious RE program necessitates stable financing that can engage, support and nudge the sector of RE towards market participation, the financing is a continuous theme over the entire technology development continuum, but, how the renewable energy sector should be financed to raise capital and what financing mode will have to finance RE are of high importance. In the light of the issues this paper will investigates the financing mode and project financing. The main support mechanisms: FIT, RPS, tax incentives, could be used to enhance renewable energy development to the desired scale [1]. This paper will reviews the three main support mechanisms used to finance renewable energy development programs. The main research issues for RE development in the following Table 82.1.

As shown in the Table 82.1, it reviews investment and financing about RE, and three main support mechanisms. Investment, financing and policies support mechanisms are the basic issues in this paper. R&D investment of RE, investment efficiency are respectively the research objects of RE investment; financing mode and project financing are the research objects of RE financing; the remainder of the research objects are the three main support mechanisms. Additionally the Table 82.1 shows corresponding methods, which are generally mathematical methods and descriptive methods. At last, the technology roadmap is shown in Fig. 82.1.

Table 82.1 Main issues for RE development: investments, financing and policies support mechanisms

Basic issues	Research objects	Research dimensions		Approaches
Investment	R&D investment of RE	R&D investment efficiency	Economic value of R&D	Discounted cash flow analysis [36] real option model [21]
			R&D investment output	Input and output model [42]
			Government subsidies and enterprise's R&D	Classical panel data analysis [57]
		R&D evaluation	Optimal level R&D of RE	Real option model [11]
			Reasonable scale of R&D	Logistic model [23]
	Investment efficiency	Economic efficiency		MCDA [31]
		Environment efficiency		panel data model [9]
		Efficiency of technologies		DEA model [3, 18, 48]

(continued)

Table 82.1 (continued)

Basic issues	Research objects	Research dimensions		Approaches
Financing	Financing mode [4, 5, 42, 55]	Financing means		Comparative method [29]
		Financing methods		Literature research [37]
		Financing instruments		Descriptive methods [4]
		Financing channels		
		Financing resources		
	Project financing	BOT		A questionnaire [59]
		CDM		Descriptive methods [28]
Policies support	Feed-in tariff (FIT)	Effectiveness of FIT	Increase cumulative capacity	Payment models [10]
			Promote RE consumption	Formal model [51]
			Carbon emission reduction	General equilibrium modeling [44]
	Renewable portfolio standard (RPS)	Comparative study RPS and FIT	Quantity of RE installed capacity	Panel data model [13]
			Technology development	Mathematical proof [50]
			Consumption of RE	quantitatively investigated [14]
		Effectiveness of RPS	Increase cumulative capacity	Panel data model [13, 56]
			Increase RE consumption	A quantitative analysis [39]
			Reduce carbon emission	
			Enhance renewable energy technologies	
	Tax incentives	Tax credits		Literature research [1]
		Carbon tax		
		Tax exemption		Descriptive methods [6]
		Capital subsidies, grants and rebates		

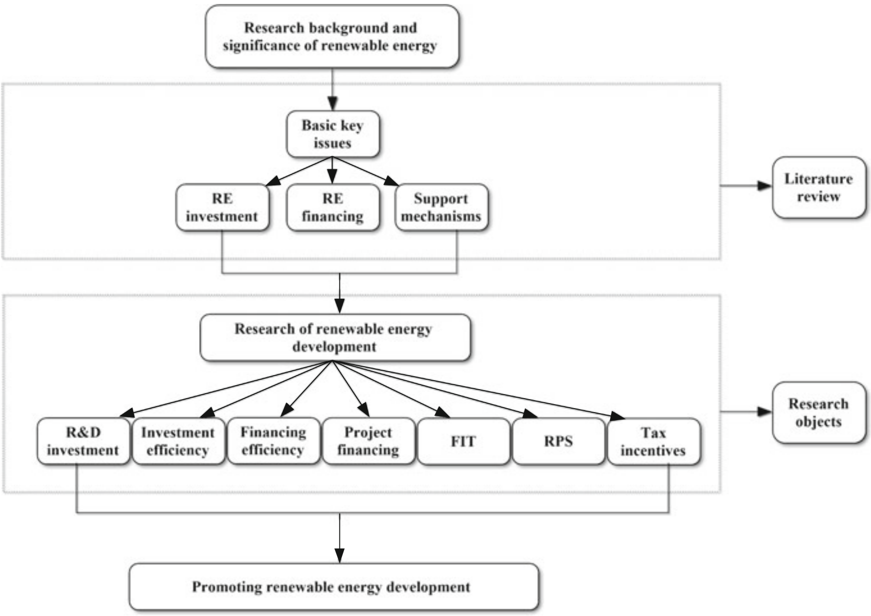


Fig. 82.1 Technology roadmap

82.3 Research for RE Investment

Developing and commercializing new RE sources requires huge initial investments [35]. R&D investment is a very important part of RE investment. In addition, investment efficiency is also the issue of RE investment needs to be considered. This section will focus on the review of R&D investment and investment efficiency.

82.3.1 R&D Investment

It was widely found that R&D expenditures support to develop [9] innovative technologies. It has become desperately necessary to make R&D investments in green technology to develop green energy. R&D is generally defined as "creative work undertaken on a systematic basis in order to increase the use of stock of knowledge to devise new applications" [33]. Potentially, it can have a highly momentous impact on economic growth and technology innovation. Because of this possibility, R&D is higher levels of competitiveness in terms of cost and technology efficiency [42]. Paper [8] applied an input-oriented DEA model to measure the ex-post performance of hydrogen energy R&D projects stressed that R&D type is a key factor influencing project performance. Recently many papers have been made to employ a technique known as real option analysis for economic valuation of R&D programs for RE. Paper [21, 36] found that there exists a considerable amount of positive economic value of investments in wind power energy R&D. A more advanced real option methodology was proposed by Martinez-Cesena [26] which combines optimization model with real option for evaluation of RE generation projects planning. Beside, some papers suggested that the level of R&D have a positive link between the efficiency of technology and R&D investment. In order to improve the R&D investment efficiency for RE technology, some papers have studied the reasonable scale of R&D investment. Lee [23] applied Logistic model forecast the penetration rate of renewable energy and determine a reasonable scale for R&D investment in renewable energy in Korea. Davis and Owens [11] estimated the value of renewable energy generation technologies using a continuous real option model determined the optimal level of RE R&D investment. Additionally, paper [2, 17] found a negative relationship between government subsidies and some renewable energy firms' R&D in terms of the amount of renewable energy technology inventions and patents. Yu [57] chose to conduct longitudinal research using classical panel data analysis models suggested that an increase in government subsidies will lead to reductions in private R&D investment.

On the above subsection, we make an overview based on the literature about R&D investment, concluding that R&D investment have positive momentous on technology innovation, can be one of the factors of influencing RE project performance, having an considerable amount of economic value. In addition, the level of RE R&D has a positive relation between the technology efficiency and R&D investment. But, some papers reveled that there is negative relationship between government subsidies.

82.3.2 Investment Efficiency

The previously main papers analyzed the efficiency at a plant or facility level, Cristóbal [48] may be the first attempt to define DMUs as technology types and analyze the efficiencies at the technology level. Madlener et al. [31] performed an assessment in terms of economic, environmental, and social criteria and corresponding indicators, DEA and MCDA techniques were used to measure the performance of biogas plants with two inputs and three outputs. DEA is also used by Chien and Hu [7] analyzed the effects of renewable energy on the macroeconomic technical efficiency with three inputs and a single output (real GDP), the results show that renewable energy has a positive effect on the technical efficiency. Barros [3] concluded that the hydroelectric plants exhibited average improvement in technical efficiency and technological change. The increase in technological change was higher than the increase in technical efficiency. Paper [18] applied a bootstrapped DEA model to evaluate the financial performance concluded that firms operating in the wind power energy sector had higher financial efficiency than firms operating in the hydropower energy sector. A similar research by Paper [30] proposed that technologies using solid wastes to generate energy should be assigned higher priority than the other options analyzed, including those fueled by natural gas and other renewable energy resources. Furthermore some papers analyzed the technologies efficiency by inputs and output. Three inputs and four outputs technology efficiency was evaluated through a Multiple Criteria Data Envelopment Analysis model by Cristóbal, the input and output data used to perform the analysis [48]. The above analysis of papers, many scholars have analyzed the efficiency from the perspective of RE technology.

As far as we concerned, the environmental efficiency is a relatively new concept, and there were only a few studies about environmental efficiency of RE investment. There are also fewer scholars analyzed the environmental efficiency at macroeconomic level for RE. An interesting perspective of assessing the environmental efficiency proposed by Morilla et al. [38] who used the Social Accounting Matrix and Environmental Accounts for Spain, in order to determine the so-called multipliers for environmental efficiency evaluation. The environmental efficiency is also found in the literature as ecological efficiency or eco-efficiency, in their research, Reith and Guidry [46] analyzed the eco-efficiency in the agricultural sector. Taking into account the need to identify a relation for the environmental efficiency of investment in green energy, Cicea [9] applied a model in a panel data approach, analyzing the environmental efficiency proposed that the regression equation for analysis of RE investments' efficiency through econometric methods will become more comprehensive.

As the scale of investment in new RE has increased, an intriguing issue of the efficiency of the investment has been raised since strategic selection and focused investment allows policy goals to be achieved with limited resources and budget. Paper [22] analyzed new RE investment efficiency with the DEA method, proposed a system model, composed of inputs, process, and outputs of new RE investment in Korea, The inputs are assumed to be made up of two elements: investments for new RE dissemination and investments for new RE technology development.

The RE policy literature has seldom incorporated the investors' perspective. Moreover, it has generally focused on the economics of energy systems, adopting market efficiency and full rationality as underlying assumptions to study the behaviors of agents [35]. The impact of non-financial factors on the RE investment—an emerging stream of literature suggests that broader social and psychological considerations must be included in the analysis of energy systems [17]. Masini et al. [35] posited that, in addition to a rational evaluation of the economics of the investment opportunities, various non-financial factors affect the decision to invest in renewables.

Investment efficiency has been mainly analyzed from technology perspective, and some scholars studied the efficiency in the perspective of environment. But, for further research, we should consider survey riskłreturn expectations, behavioral attitudes such as the non-financial factors which affect the decision to invest in RE.

82.4 Research for RE Financing

As previously mentioned, RE financing as well as investment both play an important role in promoting RE development, especially to vigorously develop RE and employ RE on a massive scale and facilitate the commercialization of RE. In the current economic context, financing has emerged as a significant barrier for sustaining the momentum gained in recent years. Given this background this section provides an overview in the perspective of financing mode and project financing.

82.4.1 Financing Mode

Scientists pointed out that the introduction and development of appropriate financing channels and instruments for both end users and industry was one of the drivers of increased investment. Financing has emerged as a significant barrier for sustaining the momentum for RE development in recent years. The main financing way of small hydropower is the market financing mode including central funds and local government supporting funds as well as other state funds [55]. As for financing means of China's wind power and photovoltaic power, it mainly includes corporate financing, project financing, and financing lease [37]. There are other domestic financing methods, other domestic financing methods of small hydropower stations in China are mainly the capital market financing, fund financing and resource financing [55]. In both China and India a number of financing instruments have been used to facilitate financing of rural renewable energy, Grants, Renewable energy service companies, Low-interest and long-term loans, Joint ventures, Asset financing, Venture capital/private equity, Subsidies, capital subsidies, donor grants, and tax rebates and similar fiscal incentives have been to the selection and delivery of financial instruments and channels [29]. Beside, closed-end is another financing instrument, and closed-end wind funds have been widely applied in Germany. Closed-fund represents a new project development approach taking advantage of the cumulated experience in the market with the existing and well-proven project role of the local citizen participation scheme [15]. Another financing method is the World Bank Group (WBG) which has steadily increased lending, especially in recent years. The WBG and other development financial institutions have supported numerous projects dealing with energy efficiency financing, including many developing countries [49]. As for debt financing and foreign currency borrowings, have come to play an increasing role in the RE scenario. Partial credit guarantees are essentially contracts between lender investor and lender-guarantor [52]. The above papers generally analyzed the financing ways such as financing instruments, means, and methods, but another perspective of financing mode to analyze the financing of RE are financing channels and resources.

Paper [4] analyzed currently financing channels: (1) Multilateral development banks, (2) The International Bank for Reconstruction and Development, (3) The International Development Association. (4) The Global Environment Facility. The financing channels of rural renewable energy of China and India mainly include government finance, international funding, commercial banks and non-bank financial institutions, public stock markets and private sector finance [52]. Delina [12] suggested that Official development assistance remains an important channel among developing countries in accessing finance for energy development. Foreign direct investment is another important determinant of financing inflows in developing economies. Multilateral agencies are another important source of development assistance. There are three main sources of funding for wind power projects and photovoltaic power projects: enterprise investment capital; bank loans and central government investment subsidies. Bank loans including loans from commercial and policy banks Loan are mainly rural infrastructure project loans from the Agricultural Development Bank [55]. In China and India international financing sources have played a major role as incubation funds for the development of rural renewable energy. The two countries both have a well-developed rural banking infrastructure [29].

Financing mode is an important issue to finance RE, However for RE further development necessitates further research on the interplay between the financial sector and policies, non-economic barriers.

82.4.2 Project Financing

AS the economy has achieved enormous growth in past decades and people's living condition is constantly improving. Electricity shortage is one significant barrier which hinders the further development of the economy and fulfilling social requirements. Incomplete financing system presents a significant challenge for renewable energy developments and affects the project costs significantly [60]. Project financing is one of the most important financing means. A common way to project financing is Build-operate-transfer (BOT) [37]. BOT projects in China were introduced as alternative project financing model to motivate private participation in RE investment. Zhao proposed that BOT is one of projects finance mode to overcome the financial problem in the development and operation of infrastructure [59]. In addition there is another financing mode: Clean Development Mechanism (CDM). CDM does help in encouraging more RE projects, especially for biomass and biogas [28]. These projects are for the most part set-up under the CDM and derive a share of their revenues by selling Certified Emission Reductions (CERs) to companies. These projects are implemented by following a set of approved methodologies and often include renewable energy [20]. CDM has been increasingly used as a supplementary source of cash flows in many renewable energy projects helping to boost the RE technologies potential in developing countries. CDM in its current form will provide a reliable long-run source of capital inflows in the renewable energy sector in developing countries [58].

Both BOT and CDM project can be described as sustainable and environmentally beneficial projects. However, easing the financing problems of RE projects, innovative financing of energy efficiency projects should be further researched.

82.5 Research for Policy Support Mechanisms

FIT and RPS are the most widely adopted policies to promote development of renewable energy. Almost all countries over the world expand the renewable energy formulate and implement at least one of these two important policies. Recent RE initiatives have originated in many countries and renewables growth in recent years also has been driven by tax incentives such as subsidies, tax credits, and other incentives. In this section, its primary concern is not the policies, but rather their effectiveness if they could promote RE generation and development.

82.5.1 Feed-In Tariff

FIT is an energy supply policy focused on supporting the development of new renewable energy projects and offers a long-term purchase agreement for the sale of RE electricity.

Some studies have held that FITs could be used for emerging technologies, such as PV, and RPS should be used to enhance near-market renewable energy technologies [1]. RE FITs contribute to cost reduction by encouraging higher growth rates, and by better encouraging long-term technological innovation [25]. But, polies can be effectiveness in promoting RE development, Government's reliable commitment and support in the form of FIT is necessary and valuable to promote wind energy development [13]. Differential equation models applied analyze three FIT mechanisms: Fix FIT, Premium FIT and FIT with contract for difference, indicated that the premium feed-in tariff and renewable obligation scheme produce the joint best results [40]. Petter [5] applied an investment decision model concluded that FIT has significantly affected the development of PV and onshore wind. Couture and Gagnon [10] analyzed a variety of FIT payment models for power generated by RE resources, arguing that the overall rate of renewable energy enhancement is influenced by the FIT payment structure and its impact on investor risk. On the other hand, many papers studied the FIT in the perspective of promoting RE consumption.

Four kinds of FIT mechanisms proposed by Hen [19], the models can motivate consumption of wind power and promote the elimination of wind power curtailment. Paper [51] compared the British FIT and RPS two policies, argued that in the perfect competition market, the two policies pay the same role, in the imperfect competition market, FIT can more to promote the consumption of RE compared to RPS, but FIT can improve the total consumption of energy. Wong [54] made a specific analysis of the FIT, concluded that the FIT policy implementation will greatly improve the consumption of solar energy in Malaysia. Schelly [44] compared RPS with FIT, argued that FIT could more effectively promote the consumption of RE and led to significant carbon emission reductions.

The papers suggested that FIT policies do in fact lead to a statistically significant increase in renewable development. Some scholars concluded that The FITs electricity produced by PV systems was still considered as competitive enough [43]. Nonetheless, on the other hand, some papers such as [40] argued that the FIT scheme is the idea that low-carbon electricity producers should receive a higher price per MWH of electricity than the market currently provides.

The reviews show that FIT established a positive correlation between in encouraging RE consumption. According to the above, FIT is an effective instrument in promoting renewable energy deployment. In addition a hypotheses should be considered that FIT can't be just a single policy could capable of solving the issue of renewable energy development, the following subsection will provide an overview of RPS that can also an important policy to promote RE generation.

82.5.2 Renewable Portfolio Standards

As previously mentioned, governments used a variety of policies to promote renewable energy development. The RPS is one of the most common policies used with FITs. As described by Rowlands [56] RPS is created to reserve a portion of the broader electricity market for renewable resources by obliging market participants to ensure that a predetermined share of their total electricity supply is provided by renewable electricity facilities.

RPS mandates to invest in energy efficiency are increasingly popular policy tools to combat climate change and encourage the deployment of renewable electricity dependence [32, 53]. RPS as well as FIT both play a positive role in promoting RE development, but many scholars suggested that there is subtle difference between the polies. Tamas et al. [47] pointed out if the markets were perfectly competitive, the two policies would achieve the same efficiencies. When the markets are imperfect, the supplies of renewable energy under FIT are higher than those under RPS. Lauber [25] compared FIT and RPS mechanisms proposed that FIT mechanism is appropriate to support renewable technology development, whereas the RPS system is more suitable in the early stage of technology development. The comparison of FIT and RPS policies showed that the RPS may be more efficient at reducing carbon emissions, but FIT is more efficient than RPS at increasing quantity of RE [19]. Espey [16] argued that RPS could not be considered a stand-alone solution that would enhance renewable energy sources. However, an RPS system should be applied after the implementation of renewable energy sources reaches a certain level. Paper [54] evaluated two alternative options of FIT, fixed and premium, the results showed that a fixed-FIT policy should be used for technologies that have not achieved high market penetration and in cases that require building a market environment. Kydes [24] analyzed federal 20 percent non-hydropower RPS on US energy markets by 2020,the estimates suggested that this policy would be effective in enhancing renewable energy technologies and reducing emissions of NOx. Eastinn [14] in his paper, by comparison of the data analysis, RPS states have increased their renewable energy production 538.1 percent more than states that have not adopted an RPS policy. Paper [56] applied a panel data model showed that RPS policies significantly affected in-state RE development and do significantly increase state renewable energy production. A quantitative analysis was applied to evaluate the energy supply generated by RE sources under the RPS mechanism in Japan, the results showed that RPS could promote the generation of winder energy [39]. Paper [13] applied panel data model to examine RPS and FIT policy mechanisms, the results show that FIT produces more wind capacity than RPS on average, with other things being equal.

According to the reviews RPS is an undoubted effective policy for the encouragement to develop renewable energy sources. Comparing FIT and RPS, both of FIT and RPS have been found to better promote RE capacity development. In future studies, more work should be done on topics such as what is the relationship of the RE market to the traditional energy generation industry, how does RE development impact other industries.

82.5.3 Tax Incentives

Tax policy is used as a useful instrument to reduce fossil fuel consumption. Tax exemption is also used as a fiscal incentive measure to enhance renewable energy deployment in many countries. Tax credits could be applied for the investment, production, or consumption segments of electricity generated by renewable energy sources. Policies aimed at encouraging renewable energy consumption could apply tax credits on the purchase and installation of renewable equipment to facilitate the penetration of renewable energy deployment into the market [1]. Capital subsidies, grants and rebates are typical instruments of the governmental organizations used to promote renewable energy sector and investment into it [4]. Pablo-Romero et al. [41] investigated a variety of instruments, and stated that tax incentives would be more effective if they were associated with a proper financing mechanism. Carbon tax is often cited by economists as an effective instrument to mitigate greenhouse gas emissions [6]. Levin et al. [27] suggested that a constant carbon tax lead to instead of generating electricity from renewable energy sources.

AS previous research, we can propose a hypothesis that there is no just single policy is capable of solving the issue of renewable energy development. Tax incentives should be combined with other policies that can lead to optimal policy outcomes. For further research, we should further study the optimal policies combination, such as what is the optimal combination of FIT and RPS and policies incentives. What is the interaction between the main support mechanisms?

82.6 Conclusion

As the scale of investment in RE has increased, the intriguing issues of the efficiency of the investment and financing have been raised since strategic selection and focused investment allows policy goals to be achieved with limited resources and budget. This paper respectively reviews the investment of RE, financing and polies support mechanisms for RE development. R&D investment and investment efficiency are respectively reviewed. The paper conclude that a few scholars analyzed the input and output efficiency of RE, but some papers analyzed the non-financing factors about determinant of RE efficiency investment. As far as this paper concerned, there is seldom study at macroeconomic level for environmental efficiency of renewable energy investment. As for financing mode many papers analyzed the financing channels, means, and financing instruments, but few paper could give analysis about the financing constraints of RE, and few scholars analyzed the correlation between investment and financing in promoting RE technologies.

As for support mechanisms, such as PRS, FIT and tax incentives can create a positive promoting for RE development. Both RPS and FIT policy could promote RE development. Many papers suggested that the FIT tends to be more effective in promoting green electricity generation than the RPS, since the latter leads to higher electricity price. But, FIT and RPS are the most common and important polices at stimulating the development of renewable industry and reducing carbon emission.

Acknowledgments This work is supported by a Program of National Natural Science Foundation of China under Grant [No. 71503216], the Social Science Twelfth Five Year Planning Project of Sichuan Province under Grant [No. SC15C051], and the Management Graduate Degree Project of Southwest University for Nationalities under Grant [No. 2016XWD-S1202].

References

1. Abolhosseini S, Heshmati A (2014) The main support mechanisms to finance renewable energy development. Renew Sustain Energy Rev 40:876–885
2. Arias AD, van Beers C (2013) Energy subsidies, structure of electricity prices and technological change of energy use. Energy Econ 40:495–502
3. Barros CP (2008) Efficiency analysis of hydroelectric generating plants: a case study for Portugal. Energy Econ 30(1):59–75
4. Bobinaite V, Tarvydas D (2014) Financing instruments and channels for the increasing production and consumption of renewable energy: Lithuanian case. Renew Sustain Energy Rev 38:259–276
5. Bolkesjø TF, Eltvig PT, Nygaard E (2014) An econometric analysis of support scheme effects on renewable energy investments in Europe. Energy Procedia 58:2–8
6. Cansino JM, Pablo-Romero MdP et al (2010) Tax incentives to promote green electricity: An overview of eu-27 countries. Energy Policy 38(10):6000–6008
7. Chien T, Hu JL (2007) Renewable energy and macroeconomic efficiency of OECD and non-OECD economies. Energy Policy 35(7):3606–3615
8. Chun D, Hong S et al (2016) Influencing factors on hydrogen energy R&D projects: an ex-post performance evaluation. Renew Sustain Energy Rev 53:1252–1258

9. Cicea C, Marinescu C et al (2014) Environmental efficiency of investments in renewable energy: Comparative analysis at macroeconomic level. Renew Sustain Energy Rev 30:555–564
10. Couture T, Gagnon Y (2010) An analysis of feed-in tariff remuneration models: Implications for renewable energy investment. Energy policy 38(2):955–965
11. Davis GA, Owens B (2003) Optimizing the level of renewable electric R&D expenditures using real options analysis. Energy Policy 31(15):1589–1608
12. Delina LL (2011) Clean energy financing at asian development bank. Energy Sustain Dev 15(2):195–199
13. Dong C (2011) Feed-in tariff vs. renewable portfolio standard: An empirical test of their relative effectiveness in promoting wind capacity development. Energy Policy 42:476–485
14. Eastin LJ (2014) An assessment of the effectiveness of renewable portfolio standards in the United States. Electr J 27(7):126–137
15. Enzensberger N, Fichtner W, Rentz O (2003) Financing renewable energy projects via closed-end funds-a German case study. Renew Energy 28(13):2023–2036
16. Espey S (2001) Renewables portfolio standard: a means for trade with electricity from renewable energy sources? Energy Policy 29(7):557–566
17. González X, Pazó C (2008) Do public subsidies stimulate private R&D spending? Res Policy 37(3):371–389
18. Halkos GE, Tzeremes NG (2012) Analyzing the greek renewable energy sector: A data envelopment analysis approach. Renew Sustain Energy Rev 16(5):2884–2893
19. He Y, Pang Y et al (2015) Feed-in tariff mechanisms for large-scale wind power in China. Renew Sustain Energy Rev 51:9–17
20. Kayser D (2013) Recent research in project finance-a commented bibliography. Procedia Comput Sci 17:729–736
21. Kim KT, Lee DJ, Park SJ (2014a) Evaluation of R&D investments in wind power in Korea using real option. Renew Sustain Energy Rev 40:335–347
22. Kim KT, Lee DJ et al (2015) Measuring the efficiency of the investment for renewable energy in Korea using data envelopment analysis. Renew Sustain Energy Rev 47:694–702
23. Kim T, Lee DJ, Koo S (2014b) Determining the scale of R&D investment for renewable energy in Korea using a comparative analogy approach. Renew Sustain Energy Rev 37:307–317
24. Kydes AS (2007) Impacts of a renewable portfolio generation standard on US energy markets. Energy Policy 35(2):809–814
25. Lauber V (2004) Refit and RPS: options for a harmonised community framework. Energy policy 32(12):1405–1414
26. Lee SC, Shih LH (2010) Renewable energy policy evaluation using real option model-the case of Taiwan. Energy Econ 32:S67–S78
27. Levin T, Thomas VM, Lee AJ (2011) State-scale evaluation of renewable electricity policy: The role of renewable electricity credits and carbon taxes. Energy Policy 39(2):950–960
28. Lim XL, Lam WH (2014) Review on clean development mechanism (CDM) implementation in Malaysia. Renew Sustain Energy Rev 29:276–285
29. Liming H (2009) Financing rural renewable energy: a comparison between China and India. Renew Sustain Energy Rev 13(5):1096–1103
30. Lins ME, Oliveira LB et al (2012) Performance assessment of alternative energy resources in Brazilian power sector using data envelopment analysis. Renew Sustain Energy Rev 16(1):898–903
31. Madlener R, Antunes CH, Dias LC (2009) Assessing the performance of biogas plants with multi-criteria and data envelopment analysis. Eur J Oper Res 197(3):1084–1094
32. Mahone A, Woo CK et al (2009) Renewable portfolio standards and cost-effective energy-efficiency investment. Energy Policy 37(3):774–777
33. Manual F (2002) Proposed standard practice for surveys on research and experimental development. Tech. rep
34. Masini A, Menichetti E (2011) The impact of behavioural factors in the renewable energy investment decision making process: Conceptual framework and empirical findings. Energy Policy 40:28–38

35. Masini A, Menichetti E (2012) Investment decisions in the renewable energy sector: An analysis of non-financial drivers. Technol Forecast Soc Chang 80(3):510–524
36. Menegaki A (2008) Valuation for renewable energy: a comparative review. Renew Sustain Energy Rev 12(9):2422–2437
37. Ming Z, Ximei L et al (2014) Review of renewable energy investment and financing in China: Status, mode, issues and countermeasures. Renew Sustain Energy Rev 31:23–37
38. Morilla CR, Diaz-Salazar GL, Cardenete MA (2007) Economic and environmental efficiency using a social accounting matrix. Ecol Econ 60(4):774–786
39. Nishio K, Asano H (2006) Supply amount and marginal price of renewable electricity under the renewables portfolio standard in Japan. Energy Policy 34(15):2373–2387
40. Oak N, Lawson D, Champneys A (2014) Performance comparison of renewable incentive schemes using optimal control. Energy 64:44–57
41. Pablo-Romero M, Sánchez-Braza A, Pérez M (2013) Incentives to promote solar thermal energy in Spain. Renew Sustain Energy Rev 22:198–208
42. Park N, Lee KJ et al (2013) In-depth analysis on R&D investment and strategy on PV in South Korea. Energy Policy 54:391–396
43. Patlitzianas KD, Christos K (2012) Effective financing for provision of renewable electricity and water supply on islands. Energy Sustain Develop 16(1):120–124
44. Proença S, Aubyn MS (2013) Hybrid modeling to support energy-climate policy: effects of feed-in tariffs to promote renewable energy in Portugal. Energy Econ 38:176–185
45. Rabe BG (2010) Greenhouse governance: Addressing climate change in America. Brookings Institution Press, Washington, D. C
46. Reith CC, Guidry MJ (2003) Eco-efficiency analysis of an agricultural research complex. J Environ Manage 68(3):219–229
47. Rigter J, Vidican G (2010) Cost and optimal feed-in tariff for small scale photovoltaic systems in China. Energy Policy 38(11):6989–7000
48. San Cristóbal JR (2011b) A multi criteria data envelopment analysis model to evaluate the efficiency of the renewable energy technologies. Renew Energy 36(10):2742–2746
49. Sarkar A, Singh J (2010) Financing energy efficiency in developing countries-lessons learned and remaining challenges. Energy Policy 38(10):5560–5571
50. Sun P, Py Nie (2015) A comparative study of feed-in tariff and renewable portfolio standard policy in renewable energy industry. Renew Energy 74:255–262
51. Tamás MM, Shrestha SB, Zhou H (2010) Feed-in tariff and tradable green certificate in oligopoly. Energy policy 38(8):4040–4047
52. Umamaheswaran S, Rajiv S (2015) Financing large scale wind and solar projects-a review of emerging experiences in the Indian context. Renew Sustain Energy Rev 48:166–177
53. Wiser R, Barbose G, Holt E (2011) Supporting solar power in renewables portfolio standards: Experience from the United States. Energy Policy 39(7):3894–3905
54. Wong S, Ngadi N et al (2015) Recent advances of feed-in tariff in Malaysia. Renew Sustain Energy Rev 41:42–52
55. Ximei L, Ming Z et al (2015) Small hydropower financing in China: external environment analyses, financing modes and problems with solutions. Renew Sustain Energy Rev 48:813–824
56. Yin H, Powers N (2010) Do state renewable portfolio standards promote in-state renewable generation? Energy Policy 38(2):1140–1149
57. Yu F, Guo Y et al (2016) The impact of government subsidies and enterprises' R&D investment: a panel data study from renewable energy in China. Energy Policy 89:106–113
58. Zavodov K (2010) Renewable energy investment and the clean development mechanism. Ssrn Electron J 40:81–89
59. Zhao ZY, Zuo J et al (2010) Critical success factors for bot electric power projects in China: thermal power versus wind power. Renew Energy 35(6):1283–1291
60. Zhao ZY, Zuo J, Zillante G (2013) Factors influencing the success of bot power plant projects in China: a review. Renew Sustain Energy Rev 22:446–453

Chapter 83
Problem of Optimal Management of Resources of Industrial Production with Given Statistical Data of Disturbance Parameters

Ali Gasan Nagiev, Firuza Allahkuli Aliyeva and Hasan Ali Nagiyev

Abstract A problem of optimum control with static quality function and with integral reachability criterion of a job for consuming control resources when perturbation distribution is known a priori has been formulated. It has been demonstrated that with the introduction of a certain structure providing feedback the problem can be reduced to a problem of stabilizing a relation of weight coefficients for optimality and reachability criteria during a process with a terminating time. Synthesis of stabilizing Lagrangian function in feedback network is made. Results of numerical analysis are given.

Keywords Stochastic systems · Optimization of planning · A feedback system · Restriction on control resources

83.1 Introduction

A number of problems from practice of production planning and other spheres of controlling static states of objects at perturbation are distinguished for the presence of integral constraint in the from of equality on the consumption being planned for control resources. The necessity of attaining a predetermined value of sectionally continuous control function integral within the fixed time creates certain analogies to familiar problems of terminal control [1, 2, 4, 8, 11]. However, these analogies are only formal. Firstly, the terminal part in this problem represent not the final state of an object at any prescribed moment of time but some deviation of the integral

A.G. Nagiev · F.A. Aliyeva
Sumgayit State University, Block 43, Sumgayit, Azerbaijan

H.A. Nagiyev (✉)
Institute of Control Systems of ANAS The Institute of Mathematics and Mechanics of ANAS, 9 F.Agayev Str., 370141 Baku, Azerbaijan
e-mail: nashfn@hotbox.ru

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_83

from control function in the course of preset period of planning. And, moreover, in the given case it is necessary to optimize static states of an object defined not by a dynamic model but by some static dependence of an exit and entry of a system, and control.

Problems with integral restrictions on control must be related to the problems which have not bean thoroughly tackled and considered so far. Only a research [5] that published recently can be taken as an example as the research directly concerned with this domain of problems. This paper raises the issue about the finding of optimal trajectory of movement of a dynamical system with a terminal restriction which is set in the form of an integral of control. Through introduction of a penalty function the authors manage to make a transition from unconditional optimization with a proof of the necessary conditions of optimality. However, in this paper the authors have formulated and solved the fully determined problem without touching upon the problem of perturbation. Despite the sufficient range of possible applications this important domain of problems related to the consideration of integral restrictions of control has not been dealt with in scientific publications. On the other hand, it is known that optimal control of static states of objects in conditions of perturbations does not present any difficulty as in case of absence of integral restriction on control the problem is solved simply, i.e., a posteriori with the advent of information on accidental external perturbation. The presence of integral restriction, however, creates a situation in which synthesis of control has to be approached from the attitudes of choosing rational structures of employing feedbacks for suppressing deviations from job [6, 9]. As one of such structures the present paper proposes some stochastic approximator implementing a certain law for stabilizing relation of process optimality criterion and satisfiability of a job of control resources consumption. The objective of the present research was mathematical formulation of a job of optimal control of a stochastic system with known statistical characteristics of perturbation when in the planning period control resources are rigorously specified.

83.2 Statement of the Problem

Let us formulate the problem in the following form:

$$\int_0^T F[x(t), u(t)dt] \to \max, \tag{83.1}$$

$$\int_0^T u(t)dt = G, \tag{83.2}$$

where $F[x(t), u(t)]$ is effectiveness function dependent on perturbation parameter $x(t)$ with familiar cumulative distribution $y = \phi(x)$ and control function $u(t)$.

A perturbation factor obeys the law of stationary ergodic process. An admissible field of control $u \in U$, time interval of planning $t \in (0, T]$, a quantity being planned of control resource consumption G as well as a certain positive number γ setting priority as a relation of weight coefficients α_0, α_1 of medium quality optimality criterion and the quantity G reachability criterion by the end of period T, respectively, are prescribed.

Let us consider the following variational problem of searching a functional maximum as a certain stochastic interpretation (equivalent) of the problem (83.1) representing a model of system with feedback established between current control and its resource being planned:

$$I\,[\phi(x), \lambda^{\mathrm{opt}}(t)] = \max_{\substack{\lambda(t);t\in(0,T] \\ \lambda(T)=\gamma=\alpha_1/\alpha_0}} \int_0^\infty \phi(x) \left\{ \max_{u\in U} \left[F(x,u) \quad -\lambda(t) \left(u - \frac{G - \int_0^t u(t)\,dt}{T-t} \right)^2 \right] \right\} dx, \tag{83.3}$$

where $\lambda(t)$ is variable function and weight coefficients α_0, α_1, make the weighted sum, i.e., $\alpha_0, a_1 \in (0, 1)$, $\alpha_0 + a_1 = 1$.

The given mathematical structure can be treated as a rule of control synthesis u in the rate of emergence of random perturbation x if a variational problem of searching optimal Lagrangian function $\lambda^{opt}(t)$ due to static characteristics of this perturbation is previously solved.

At moments t_n; $n = 1, 2, \cdots, N-1$; $t_N = T$ of bringing optimizer into operation in control process itself control $u(t_n)$ for arbitrary t_n can be related to perturbation $x(t_n)$ owing to quality optimality requirement $F(x, u)$. Furthermore, thanks to the fact that in Eq. (83.3) feedback is realized which regulates the deviation of integral value from the prescribed parameter G, i.e., due to definiteness of the value

$$g(t_n) = \frac{G - \int_0^{t_n} u(\tau)d\tau}{T - t_n} \tag{83.4}$$

at arbitrary moments of time it is possible to pass to finite-dimensional problem of searching a maximum of function

$$\max_{u_n\in U} \left[F(x, u_n) - \lambda^{\mathrm{opt}}(t_n)(u_n - g(t_n))^2 \right]; n = \overline{0, N-1} \tag{83.5}$$

at each current t_n.

Thus, by stating the problem of determination of optimal function $\lambda^{\mathrm{opt}}(t)$ from the functional (83.3), in essence, a premise is put forward about isomorphism of the problems (83.1) and (83.5) from the viewpoint of finding optimum control strategy $u(t)$; $t \in (0, T]$ with consideration for function $\phi(x)$ and measures of preference of criteria $\gamma = \alpha_0/\alpha_1$.

83.3 Algorithm of Problem Solution

We will conduct normalization through introduction singly of scales for estimation of optimality and reachability. Let us consider function:

$$\Phi\left(x, u(t)\right) = e^{\mathrm{qua}} F\left[x, u(t)\right] - e^{\mathrm{acc}} \lambda(t) \left(u(t) - \frac{G - \int_0^t u(t)dt}{T - t} \right)^2. \tag{83.6}$$

Scale coefficients e^{qua}, e^{acc} will be determined on the basis of the following differences calculated at $x = M[x]$:

$$e^{\mathrm{qua}} = \left[\max_{\substack{x=M[x] \\ u \in U}} F(x, u) - \min_{\substack{x=M[x] \\ u \in U}} F(x, u) \right]^{-1}, \tag{83.7}$$

$$e^{\mathrm{acc}} = \left[T \cdot \left| \arg \max_{\substack{x=M[x] \\ u \in U}} F(x, u) - \arg \min_{\substack{x=M[x] \\ u \in U}} F(x, u) \right| \right]^{-1}, \tag{83.8}$$

where $M[x]$– mathematical expectation.

Let us introduce a normalizing coefficient as a ratio of chosen scales:

$$\lambda_0 = \frac{e^{\mathrm{acc}}}{e^{\mathrm{qua}}} = \frac{\max_{\substack{x=M[x] \\ u \in U}} F(x, u) - \min_{\substack{x=M[x] \\ u \in U}} F(x, u)}{T \left(\arg\max_{\substack{x=M[x] \\ u \in U}} F(x, u) - \arg\min_{\substack{x=M[x] \\ u \in U}} F(x, u) \right)}. \tag{83.9}$$

We will write maximization problem with consideration for the normalizing coefficient:

$$\max_{u \in U} \Phi\left(x, u(t)\right), \forall t \in (0, T), \tag{83.10}$$

where

$$\Phi\left(x, u(t)\right) = F\left[x, u(t)\right] - \lambda_0 \lambda^{\mathrm{opt}}(t) \left(u(t) - \frac{G - \int_0^t u(t)dt}{T - t} \right)^2, \forall t \in (0, T). \tag{83.11}$$

Stochastic approximation in the given case is the search for optimal $\lambda^{\mathrm{opt}}(t)$ in the assumption of statistical consistency of samples of observational date on random quantity $x(t)$ realized over time interval $t \in (0, T]$.

At first we will analyze the given problem leaving feedback depth unchanged throughout the whole period of planning, in particular, let us say that $\lambda(t) \equiv \gamma$.

Let us suppose that inverse function is found:

$$x = \phi^{-1}(y); \quad y \in (0, y_{\max}], \tag{83.12}$$

where y is probability density value, $y_{\max}$ is extreme point of interval with values of function $y = \phi(x)$.

Without touching upon the issue of possible ambiguity of the inverse function (83.11) for the time being, i.e., taking it to be single-valued, we will consider this in (83.10). By doing go we get an opportunity to offer for consideration some function at an arbitrary moment t:

$$y_1 = \varPhi U\mathrm{M}\ (y, \lambda(T))\,; \quad y \in (0, y_{\max}] \tag{83.13}$$

representing distribution density y_1 of random quantity $u^{\max}$ by means of expressions (83.10), (83.11), function $y = \phi(x)$ as well as the chosen quantity $\lambda(T) = \gamma$.

It is obvious that from the function $\varPhi UM\ (y, \cdot)$ one can compute mathematical expectation of control $M[u^{\max}(y), \lambda]$ providing a maximum of function (83.10) at an arbitrary quantity λ.

Let us suppose that we have some time sequence $t_i, \; i = 1, 2, \cdots$ of employing an optimizer, i.e., of computing values $u^{\max}[x(t_i)], \; i = 1, 2, \cdots$ presenting maxima of the function (83.10) at the prescribed moments. Now we will analyze the origin of the mistake basing on the estimate of mathematical expectation. Let $\hat{M}\{u^{\max}[x(t_i)]\}$ be mathematical expectation computed from an ensemble of empirical material accumulated through maximization of the function (83.10). Let us note that owing to statistical completeness of the data samples it must be sufficiently exact approximation of parameter $M[u^{\max}(y)]$ analytically computed from Eq. (83.13). Because of arbitrariness of the chosen $\lambda(t) \equiv \gamma$ in Eq. (83.11) it is obvious that both values will not coincide with medium intensity of consumption resource G/T. Then over time $t \to T$ in consequence of the accumulation of deviations $\varDelta(t) = \int_0^t \left(u^{\max}(\tau) - \frac{G}{T}\right) d\tau$ relationship of mathematical expectations of the components of the expression (83.10) will turn out to be time function. This will mean that control strategy of parameter u becomes dependent on the accumulation of deviations from the average speed of consumption of control resources $\frac{G}{T}$ at stationary ergodic perturbation $x(t)$, i.e., at perturbation with probabilistic parameters not varying with time. Hence, tackling the reverse problem, i.e., having created a tracking system it is possible to require constancy of mathematical expectation of control $M[u^{\max}(t)] = \text{const}$ over the period $t \in (0, T]$ at the expense of dynamically running correction λ. As a specific value of this function relative to conditions of the problem can be computed at the final point of an interval, i.e., because the estimate $\lambda(T) = \gamma$ as the prescribed value is known and the estimate below

$$M\left[u^{\max}\,(t)\right] = \frac{G}{T}, \tag{83.14}$$

following from the abovementioned conclusion about invariability during the period $t \in (0, T)$ of mathematical expectation for optimum solution is true, then it is possible to create an iterative process of tuning $\lambda(t_s)$; $s = \overline{S-1, 0}$ in reverse sequence in relation to the course of time beginning, iterative computations from pre-final of the interval t_{S-1} towards the beginning to.

In accordance with the very stabilization strategy of mathematical expectations we will write a scheme of iterative computations in the from:

$$\lambda(t_{s-1}) = \arg\min_{\lambda(t_{s-1})} \left(M[u^{\max}(t_s), \lambda(t_{s-1}), \lambda(t_s)] - \frac{G}{T} \right)^2, s = \overline{S-1}, 0, \quad (83.15)$$

in which quantities $M[u^{\max}(t_{s-1}), \lambda(t_{s-1}), \lambda(t_s)]$ can be determined on the basic of Eqs. (83.10) and (83.11) with the use of the following stochastic approximation of quantity $g(t_s)$ in them:

$$g(t_s) = \frac{G - \sum_{p=S}^{s} M\left[u^{\max}(t_p), \lambda(t_p)\right] \left(t_p - t_{p-1}\right)}{T - t_s}; \quad s = \overline{S-1}, 1. \quad (83.16)$$

So, it turns out that mathematical expectation of optimum control $M[u^{\max}(t_s)]$ at the moment of turning t_s determined as theoretical first initial statistical moment from the function (83.13) is recurrently related to the total deviation from mathematical expectation at the preceding iterations. Synthesis of optimum variant of the sequence $\lambda(t_s)$ can be made on the basis of recurrent computations being performed in reverse course of time, i.e., by arranging iterative computations from the end of a planning interval towards its beginning.

It should be noted that computation of quantity $M[u^{\max}(t_{s-1})]$ may have a disadvantage which shows itself in ambiguity of inverse function $x = \phi^{-1}(y)$ more often encountered in practice [3].

For this reason in common use is interval consideration of a prescribed function with the performing of computations of mathematical expectation by parts on the basis of composition-of-probabilities theorem.

83.4 Analysis of Solution Nature

A number of details of synthesis of function $\lambda^{\text{opt}}(t)$ are visually displayed using the following modeling problem as an example:

$$F = \frac{1}{1 + axu^2}, 0.5 < u < 2; 0 < x < \infty, \quad (83.17)$$

at $a = 1$, $\phi(x) = \frac{1}{b} e^{-\frac{x}{b}}$, $G = 1$, $T = 1$.

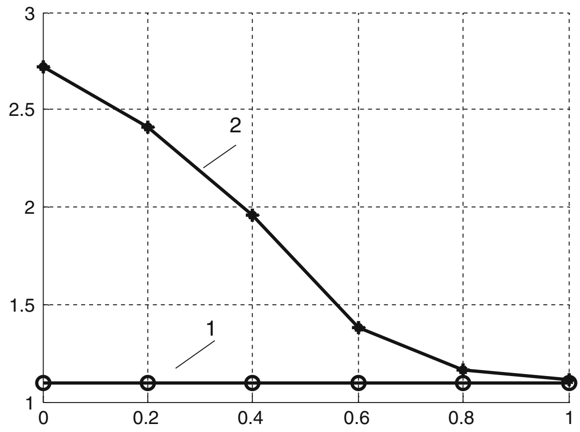


Fig. 83.1 Numerical solution of the problem of synthesis of $\lambda^{\mathrm{opt}}(t)$ for the model (83.17) when $\lambda^{\mathrm{opt}}(T) = 1$

Results of numerical solution are presented in Fig. 83.1. A variety of solution variants with different values of parameter b are studied, in particular, Fig. 83.1 demonstrates a variant when $b = 1$. The interval $[0, T]$ was divided into 5 portions with nodal points of carrying out iterative process of synthesis of function λ_s; $s = \overline{1,\ 5}$ using recurrent formulae (83.15), (83.16).

At first the computational experiment for estimating the result of synthesis was conducted at non-varying weight coefficient, i.e., $\lambda(t) \equiv 1$ in the problem (83.17). The simulation of external effect $x(t)$ was performed by means of a signal from the outlet of a generator of pseudorandom numbers which realizes the mentioned cumulative distribution function with parameter $b = 1$. The number of connections of an oscillating element as a part of this generator throughout the whole prescribed period T was $N = 4000$.

An oscillogram of the control function $u(t)$ for this realization of the computational experiment can be seen in Fig. 83.2.

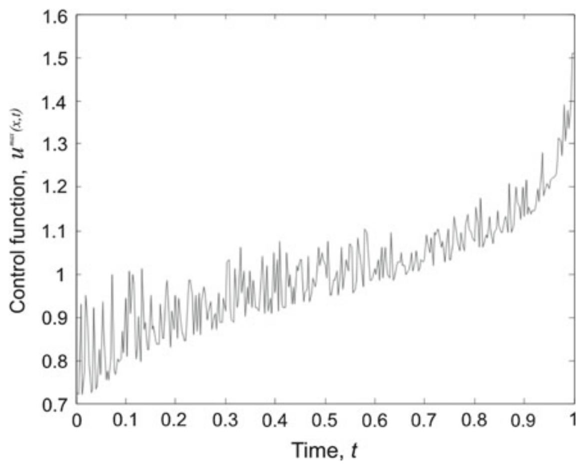


Fig. 83.2 The control oscillogram at a signal from the generator of pseudorandom numbers with distribution of $phi(x) = \frac{1}{a}e^{-\frac{x}{a}}$ when $\lambda(t) \equiv 1$

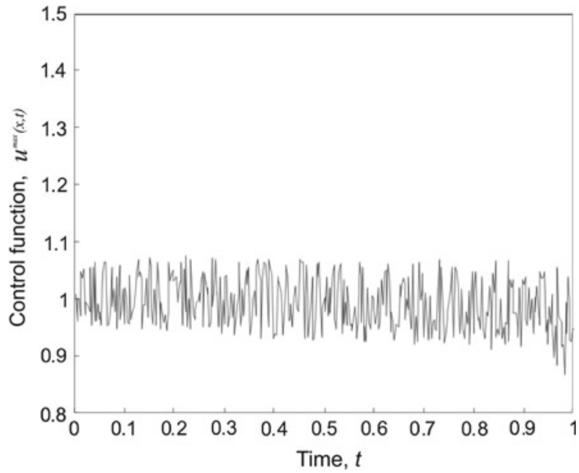


Fig. 83.3 Control oscillogram at the optimum stabilizing function $\lambda^{\mathrm{opt}}(t)$ for the problem (83.17)

The presented oscillogram clearly demonstrates a trend of increase in the average value of the function $u(t)$ as the end of planning period approaches. This is caused by sufficiently tangible value of negative deviation of mathematical expectation from the average value, i.e., increase in the value of $\left|\frac{G}{T} - M[u^{\max}(x)]\right|$. Initially, an efficiency function is more sensitive to an index of process optimality than to that of reachability. This is indicated by comparatively high amplitudes at the initial and middle portions of the period. As the end of planning period approaches "the making up for lag" at the expense of large deviations takes place in the terminal portion while oscillation amplitudes, on the contrary, are reduced.

Figure 83.3 shows a process that is self-attuning already and is realized by means of the synthesized function $\lambda^{\mathrm{opt}}(t)$. As seen, in this case the uniformity of distribution of the relation between optimality and reachability criteria of the prescribed integral constraint due to which a trend of the average value of optimum control $u(t)$ is invariable.

By performing a series of computational experiments a number of properties of solutions for synthesis of the functions $\lambda^{\mathrm{opt}}(t)$ have been revealed. These solutions turned out to be especially sensitive to a relation of end parameters, i.e., $\frac{G}{T}$ value, to model parameters and statistical parameters of perturbation.

We will isolate two critical variants from a variety of function $\lambda(t)$, namely; $\lambda(t) \equiv 0$ and $\lambda(t) \equiv \infty$. When $\lambda(t) \equiv 0$ we have a problem without constraints on control resources. When $\lambda(t) \equiv \infty$ we have a formula without consideration for quality optimality. That is why we will introduce the following designations:

$$u^{\max}_{\lambda=0} = M \left\{ \arg \max_{\substack{y \in (0, y_{\max}) \\ \lambda(t) \equiv 0 \\ u \in U}} \Phi[\phi^{-1}(y), u] \right\},$$

$$u^{\max}_{\lambda=\infty} = M \left\{ \arg \max_{\substack{y \in (0, y_{\max}) \\ \lambda(t) \equiv \infty \\ u \in U}} \Phi[\phi^{-1}(y), u] \right\},$$

which stand for mathematical expectations of control providing a maximum of the function $\Phi(\cdot)$ by substituting $x = \phi^{-1}(y)$; $y \in (0, y_{\max})$ according to the two critical variants of Lagrangian function, namely: $\lambda(t) \equiv 0$ and $\lambda(t) \equiv \infty$.

On account of properties of the functions $F(x, u)$, $\phi(x)$, given by a set U as well as by a value of $\frac{G}{T}$ relation there can be at least five characteristic signs of the sought functions $\lambda^{\text{opt}}(t)$ and functions indicating dynamics of control resource $g(t)$ during period T.

Figure 83.4 presents graphs of Lagrangian functions with finite value $\lambda(T) = 1$ computed for five chosen variants of setting conditions; Fig. 83.5 shows graphs of functions of control resource dynamics corresponding to them. The graphs are obtained using solutions of five variants of modeling problems.

Figures 83.4 and 83.5 are respectively, optimum Lagrangian functions and those of consumption resource dynamics in five variants of conditions of the problem.

Variant 1: The choice of parameters in this variant is made on the basis of necessity of attaining the critical point which is expressed by this equality: $u^{\max}_{\lambda=0} = u^{\max}_{\lambda=\infty} = 1.2$; (parameters; $a = 0.37$; $b = 1.8$; $G = 1.2$; other parameters correspond to the

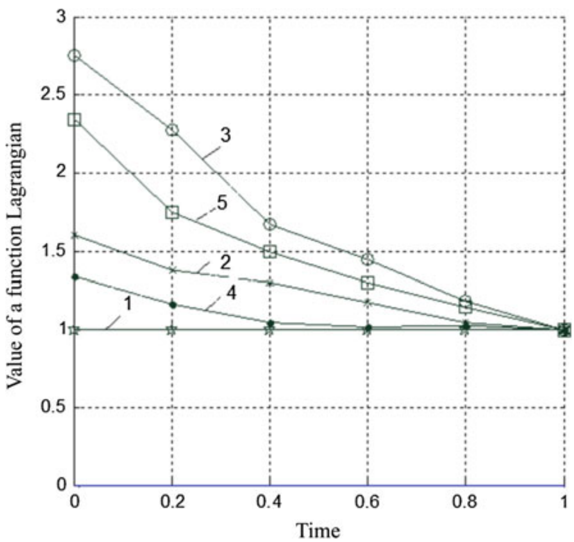


Fig. 83.4 Five characteristic signs of initial date of the problem influencing solutions of $\lambda^{opt}(t)$ and $g^{opt}(t)$

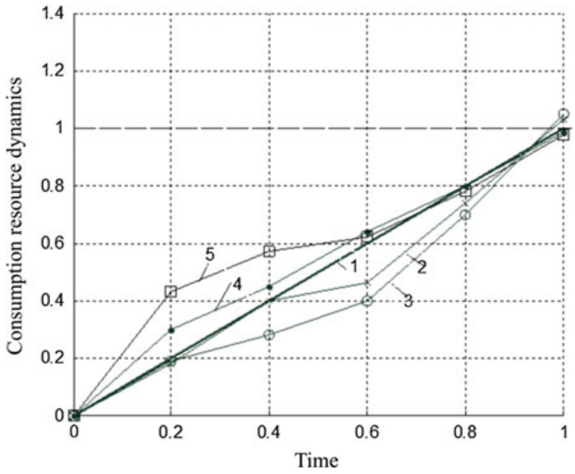


Fig. 83.5 Five characteristic signs of initial date of the problem influencing solutions of $\lambda^{opt}(t)$ and $g^{opt}(t)$

initial date of the model (83.17). The straight lines in Fig. 83.1 correspond to this variant.

Variant 2 (curve 2) characterizes the problem: $u^{\max}_{\lambda=0} > u^{\max}_{\lambda=\infty}$ $(a = 0.87;\ b = 1;\ )$; $u^{\max}_{\lambda=0} = 1.2$; $u^{\max}_{\lambda=\infty} = 1$.

Let's reduce following alternatives:

Variant 3 (curve 3): $u^{\max}_{\lambda=0} >> u^{\max}_{\lambda=\infty}\ \left(a = 2.17;\ b = 1; u^{\max}_{\lambda=0} = 2.4; u^{\max}_{\lambda=\infty} = 1\right)$.

Variant 4 (curve 4): $u^{\max}_{\lambda=0} < u^{\max}_{\lambda=\infty}\ \left(a = -0.18;\ b = 2;\ u^{\max}_{\lambda=0} = 0.72; u^{\max}_{\lambda=\infty} = 1\right)$.

Variant 5 (curve 5): $u^{\max}_{\lambda=0} << u^{\max}_{\lambda=\infty}\ \left(a = -0.53; b = 2; u^{\max}_{\lambda=0} = 0.18; u^{\max}_{\lambda=\infty} = 1\right)$.

Analysis of the solutions of the test problem has led to the conclusion that independently of the sign of the difference $u^{\max}_{\lambda=0} - \frac{G}{T}$ Lagrangian function does not undergo any qualitative changes. At the same time the variants (curve 3, curve 5) characterized by significant differences in $u^{\max}_{\lambda=0},\ u^{\max}_{\lambda=\infty}$ values are more dependent on a stabilizing effect of Lagrangian function $\lambda(t)$ and less stable in relation to consumption resource dynamics (see Fig. 83.5).

83.5 Conclusion

The problem of optimizing stationary states of objects with consideration for integral constraints in the form of equality on control resources can be solved using the proposed feedback structure. In this process an algorithm of positional control calls for the solution of the problem of synthesis of optimum stabilizing Lagrangian function relative to all conditions of a specific problem including distribution function of external perturbance, specific quality function, admissible field of control and weight coefficients of priority of medium quality optimality and reachability criteria.

For problems with sufficiently prolonged interval of control when arbitrary realization of a random signal reliably conveys its statistical parameters programmed control of weight coefficients for optimality and reachability criteria will more reliably guarantee optimality of the process on the whole. An indicator of this optimality proves to be the stability of the prescribed relations of the said criteria throughout the interval of positional control of the process.

References

1. Alekseev VM, Tikhomirov VM, Fomin SV (1979) Optimum control. Nauka, Moscow
2. Alexandrov VM (2011) Optimum under the charge of resources control of the linear systems. Calc Math Math Phys Log 4:562–579
3. Douglas C (2014) Applied statistics and probability for engineers. Wiley, New York
4. Evdokimov SN (2012) The terminal control algorithm a longitudinal motion of a lander with overloading restriction. Inf Russ Acad Sci 5:102–117
5. Fominyh AV (2015) Necessary conditions for a minimum of a polynomial of integral functionals 2. St. Petersburg State University, Saint Petersburg
6. Krasilshchikov MN (2011) Homing guidance of the high-speed pilotless aircraft on a terminal section of an atmospheric flight. Theory Control Syst 6:128–143
7. Krasovsky NN (1968) Control theory traffic. Nauka, Moscow
8. Kurzhansky AB (1978) About informational assemblage of controllable systems. Rep Acad Sci USSR 240(1):14–17
9. Lazarev JN (2007) Control paths of space meanses. The Samara Centre of Science of the Russian Academy of Sciences
10. Letov AM (1981) The mathematical theory of managerial processes. Nauka, Moscow
11. Ostrem KJ (1973) Introduction in stochastic control theory. Wiley, Moscow

Chapter 84
The Multi-factor Multi-region Decomposition Method for Carbon Emission Reduction

Can Ding, Jing Li and Dong He

Abstract The carbon emission reduction has become a matter of grave concern all over the world. How to decompose the carbon emission reduction task effectively is the key to achieving the target successfully. In this paper, we will propose the multi-factor multi-region decomposition method for carbon emission reduction, which can take both many factors that influence carbon emissions, and different characteristics of each region into consideration. A combination weight method is used to calculate the weights of the indicators. Finally, the result of the empirical study shows the efficiency of the proposed method.

Keywords Carbon emission reduction · Multi-factor · Multi-region · Decomposition method

84.1 Introduction

Human beings have changed the natural environment with increasingly complex activities for a long time, such as the rapid development of the industrial revolution, in order to improve the living standards, and affected the earth upon which mankind depends for survival. The carbon dioxide (CO_2), methane and other greenhouse gases make the earth warmer and warmer, in which the contribution of CO_2 to greenhouse effect is the biggest. Different forms of carbon emission will affect the distribution of temperature, precipitation and other meteorological parameters, and then affect the world economy in many aspects, such as agriculture, energy production, and so on. The increasing greenhouse gases not only bring unprecedented crisis to the global environment, but also bring people endless disasters and threats.

C. Ding · D. He (✉)
Xihua University, Chengdu 610064, People's Republic of China
e-mail: 812979783@qq.com

J. Li
Sichuan Academy of Social Sciences, Chengdu 610064, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_84

To cope with the issue of global climate change, from the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 to the Kyoto Protocol in 1997, from the Copenhagen World Climate Conference in 2009 to the Paris World Climate Conference in 2015, the world united on this common goal of controlling carbon emissions. Many countries set the corresponding targets, and established some guarantee measures. The United States government promised to reduce greenhouse gas emissions by 26–28 % in 2025 compared with that in 2005. The European Union promised to reduce greenhouse gas emissions by 40 % in 2030 over 1990, while increased the proportion of renewable energy by 27 %. China made the goal of reducing CO_2 emissions per unit of GDP by 60–65 % in 2030 over 2005. However, how to decompose the overall objectives of the whole country, so as to guide the provinces and cities to achieve their goals, is an issue worthy of further research.

Decomposition analysis (DA), as an approach to study the characteristics and mechanism of how things change, gets more and more application in recent years. DA represents a different research stream, which is also widely recognized as a powerful tool to face the complexity of the real world. The common decomposition methods are Structural Decomposition Analysis (SDA), and Index Decomposition Analysis (IDA) [8].

The SDA decomposes a comprehensive variable into several influence factors, and analyses the impact of each factor which affects the comprehensive variable. The formal research of SDA originated in the dynamic analysis of the investment and technology development by Carter [3]. The classic thesis of Skolka [17] is one of the research work which is frequently cited. Shrestha and Timilsina [15] are the first to use the Divisia method for decomposing changes in CO_2 intensity of 12 Asian countries. The reference [1, 7, 10, 12, 19] are also about SDA applying. All of the studies listed apply only single-region input-output frameworks to carry out the SDA, even when the study involved groups of countries. Only Kagawa and Inamura [10] employ a multi-region input-output (MRIO) framework in their study, using the China-Japan inter-country IO tables to measure the effects of changes in energy demand. Domestic research and application about SDA originated from Chen and Guo [5].

IDA is put forward in the 1920s, mainly has more than ten forms, and Laspeyres, Divisia, Paasche, Fisher and Marshall-Edgeworth, and the Laspeyres and Divisia decomposition methods are most used in the application research. Shrestha et al. [16] used the Log Mean Divisia Index (LMDI) method for the decomposition of CO_2 emissions from the power sector in fifteen countries in Asia and Pacific. Malla in [11] used also LMDI to decompose changes in CO_2 emissions from electricity production in Asia, Pacific and North American countries. Steenhof and Weber [18] used the Laspeyres decomposition method for assessing the factors affecting changes in GHG emissions in Canada's electricity sector between 1990 and 2008. Zhang et al. [20] investigated changes in CO_2 emissions from the power sector in China using LMDI and found that the economic growth effect made the biggest contribution for the rising CO_2 emissions. As the Laplace index Method and the vast majority of D-index have some defects, Ang and Liu [2, 20] gave the improved Method, puts forward modified Laspeyres, LMDI I and LMDI II.

Based on the analysis above, many scholars have done a lot of work on the decomposition method, but little research is involved multiple regions decomposition. To combine multiple regions decomposition with multiple elements decomposition, and decompose the state's overall mission into several tasks for provinces, is limited by lack of relevant studies. This paper will propose a multi-factor multi-region decomposition method and apply the method to decompose the carbon emission reduction targets.

84.2 Problem Statement

In recent years, the rapid increase of CO_2 emissions is one of the main reasons which has caused global warming and rise of sea level. With a large population and relatively low level of economic development, China is in the crucial stage of where industrialization and urbanization development is speeding up, and in consequence controlling greenhouse gas emissions is facing huge pressure and special difficulty.

(1) Large quantity of emissions. According to the data of world's greenhouse gas emissions, China has been the first in global carbon emissions in recent years. Because China has just entered the intermediate stage of industrialization, and still in a period of rapid growth of energy demand and consumption, CO_2 emissions will increase along with the growth of the economy in a long term in the future.

(2) Multiply industrial emission source. Industrial emission source mainly refers to the production process of iron and steel, nonferrous metallurgy, inorganic chemicals, organic chemicals, non-metallic minerals and so on. Industrial emissions sources of CO_2 are not only in large number, but also distribute dispersedly.

(3) Fast growth. China is among the few energy consuming countries that are given priority to coal in the world, CO_2 emissions are mushrooming so rapidly with China's economic growth. According to the statistics of CO_2 information analysis center, the change trend of China's carbon emissions from 1980 to 2012 is as shown in Fig. 84.1. As for dependence on clean energy increases, China's CO_2 emissions may reach the peak in 2020 and 2035.

(4) Great regional differences. At present, the status of CO_2 emissions in the Chinese provinces is significantly different. In Chinese districts, gross emissions decrease progressively from the east coastal regions to central and western regions. As far as emission intensity (CO_2 emissions per unit of GDP) is concerned, it's high in northwestern and southwestern regions, low in central and eastern regions, and is obviously in the lower level of the country in southeastern-southern coastal line. On June 30th 2015, China formally announced Enhanced Actions on Climate Change: China's Intended Nationally Determined Contributions (INDC), and put forward the action goal to make response to climate change in 2030, and set new goals such as 60–65 % lower CO_2 emissions per unit of GDP in 2030 than in 2005. Considering that China is still a developing country, CO_2 emissions are inevitably rising for the development of the economy to improve the livelihood of the people, and it's a long way to go for reducing CO_2 emissions in China. Therefore, CO_2 emission reduction

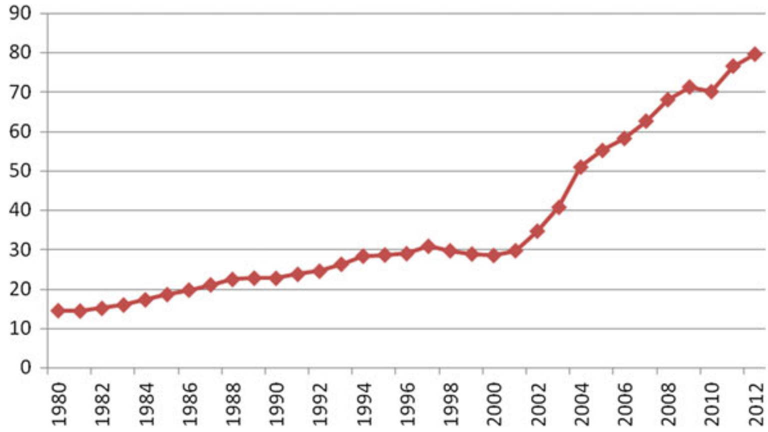


Fig. 84.1 Group conflict coordination framework for emergency decision

targets must be reasonably decomposed to the various provinces and cities according to their economic strength and corresponding responsibilities, so as to guarantee the smooth realization of the carbon emission reduction task.

Whether the decomposition method is scientific and reasonable is not only related to the accuracy of the decomposition results from all provinces and cities, but also related to the scientificity of environmental protection planning for our country, provinces and cities. Firstly, we should abandon the decomposition methods such as "one size fits all" and average distribution. Secondly, we should improve unreasonable decomposition method aiming at single indicator, and consider each factor such as the society, economy and environment. In addition, we need to analyze various historical objective data instead of using forecasting and decomposition method based on just one year data in existing literature. This paper puts forward the multi-region decomposition method based on multi-factor on the basis of summary of present decomposition methods research at home and abroad, and the basic steps are: analysis of indicator's current situation, determining of the influencing factors, selection of the appropriate method of weight, reasonable weight, obtaining regional comprehensive indicator, and final determining the decomposition proportion of target indicators according to the appropriate comprehensive indicators.

84.3 The Multi-factor Multi-region Decomposition Method

The basic steps for the multi-factor multi-region decomposition method are as follows:

(1) To analyze the economic society, energy and environment situation and future development trend within the scope of various provinces and cities, and determine the factors that influence the indicator decomposition;
(2) To calculate the impact factor of each element, that is to determine the weight;

(3) To calculate comprehensive indicator of various provinces and cities based on the score of various factors, and comprehensively evaluate comprehensive indicator by parallel comparison with annual data by considering the development trend of various provinces and cities in the future;
(4) To decompose the planning indicator after determining the comprehensive indicator of various provinces and cities according to the proportion of comprehensive indicator in those provinces and cities.

The selection of influencing factors and appropriate approach to weight is the key procedure of the method, and this chapter will analyze the two key links.

84.3.1 Selecting Influence Factors

Social and economic development interact with resources and environment. On the one hand, the social and economic development is the primary influence factor of resource utilization and environmental pollution, the demand for production materials and living materials in the process of the production and consumption is the root cause of resource utilization. Resource utilization is insufficient under the condition of existing technology, which leads to wasting and emissions of non-production and non-living purpose that in effect causes environmental pollution. On the other hand, resource and environment also restricts social and economic development, resource bottleneck and environmental pollution will in turn limit the further economic growth and social welfare improvement. Economy, society and environment balance comprehensively and develop coordinately with one another, so the research of resources cannot be limited within the environmental system. We should research one of the three systems as a whole instead of only taking economic and social development situation into consideration.

As for indicator decomposition related to environment, such as CO_2, the first thing to consider is regional development status and the influencing factors, and second one is all kinds of factors that influence the trend of economic development, resources and energy consumption and pollutant emissions in various areas in the future. Then we can select decomposition model, determine the factor weights, calculate the comprehensive indicator and so on.

84.3.2 Calculating Factors' Weights

After the influence factors of indicators are selected, the key work is to determine the weights of influence factors. There are a lot of methods to determine the weight coefficient, and when we build a weight by all kinds of methods, the original data available can be subjective or objective, so weight methods can be divided into three categories from the perspective of data source: namely the subjective weight method, objective weight method and combination weight method based on the former two methods. The subjective weight method, based on the importance of each index, is an artificial empowerment method, and fully reflects the experts' experiences. For now, the most used methods are the Delphi Method [14], and Analytic Hierarchy Process (AHP) [6], etc. The objective weighting method is the weight method based on the objective information of actual data, such as the Entropy Method (EM) [13], Factor Analysis (FA) [4], Principal Component Analysis (PCA) [9], Variation Coefficient Method (VCM), etc. Considering the advantages and disadvantages of both methods, researchers put forward a combination weight method. The specific methods please refer to the relevant literature.

84.4 Empirical Study

This section gives a practical application for the proposed method. The empirical study is based on the statistical data of 2009–2011, as the data in the last few years is not complete.

84.4.1 Factor Selection

(1) Initial Indicator

From the previous analysis, we know that factors that may affect CO_2 emissions in China mainly consist of economy, population, industry and technology, etc. The following analysis is to find out the related measuring indicators.

① Economic factors

The rapid economic development of our country requires investing a lot of fossil fuels, such as coal, oil and natural gas, moreover, it's bound to produce a large number of CO_2 in the process of economic development which is decided by the energy consumption structure (mainly coal-oriented) in China. According to the overall data of the world, CO_2 emissions grew with almost the same speed as that of GDP per capita. So we choose GDP and GDP per capita to measure the level of economy of provinces and cities.

② Demographic factors

Population growth is the important factor that affects CO_2 emissions. First of all, more population requires more energy, then CO_2 emissions generated from energy consumption will be more and more, so we think that the total population has incremental effect on CO_2 emissions. Secondly, age structure also has certain influence on CO_2 emissions. And herein we use two indicators to measure demographic factors: the total population and proportion of 15−64-year-old population in total population.

③ Urbanization factors

Urbanization rate has certain effect on CO_2 emissions, usually the higher proportion of urban population is, the more energy and resources consume. So we choose the proportion of urban population in total population to measure the factors of urbanization.

④ Industrial structure factors

Due to the different types and structures of energy that different industrial sectors consumed, CO_2 emissions may be not identical. According to the statistics, China's terminal energy consumption of industrial sectors accounts for more than 60 % of all terminal energy consumption, more than 50 % of all terminal coal consumption and more than 70 % of the total electricity consumption. Therefore, the proportion of industrial added value in total GDP is selected to measure the proportion and structure of industry in various provinces and cities.

⑤ Technology factors

Technology progress is one of the significant ways to solve environmental problems, and it also plays an important role in reducing CO_2 emissions. Taking advantage of a variety of advanced low carbon technologies will be beneficial to improve the energy consumption, save energy, enhance energy efficiency and reduce CO_2 emissions. Here, energy consumption per unit GDP (energy consumption/total GDP) stands for energy intensity, the proportion of research and development (R&D) funds in a certain area in financial expenditure as a proxy variable to some extent reflects the provincial scientific and technological progress.

On the basis of the above analysis of all kinds of factors, the influence factors in various regions which affect CO_2 emissions can be measured by 8 indicators, they are: X_1 is GDP (Unit: hundred million yuan), X_2 is GDP per capita (Unit: yuan), X_3 is population (Unit: ten thousand people), X_4 is the proportion of 15−64-year-old population in total population (Unit: %), X_5 is the proportion of urban population in total population (Unit: %), X_6 is the proportion of industrial output value in total GDP (Unit: %), X_7 is energy consumption per unit GDP (Unit: Mtce/ ten thousand yuan), X_8 is the proportion of R&D in financial expenditure (Unit: %). Among them, data of GDP, GDP per capita, population, the proportion of urban population in total population, and energy consumption per unit GDP can be obtained directly from national statistics yearbook, and other data can be calculated on the basis of raw data according to the national statistical yearbook. Table 84.1 lists the relevant indicators in 30 provinces and cities in China in 2011 (data of energy consumption in Tibet is missing). As shown in Table 84.1, since the forms of indicators value are different, and measurement is also different, the data cannot be directly comparable. Due to the correlation among multi-factor, such as X_2, X_6, X_7 are associated with X_1, X_4, X_5 are related to X_3, X_2 and is related to X_3, we use principal component analysis to deal with the original indicators in order to reduce the complexity of the problem.

(2) PCA

The calculating process of PCA is shown as follows.

Table 84.1 The indicators of 2011

Region	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Beijing	16251.93	81658	2019	70.41	86.18	18.76	0.46	5.64
Tianjin	11307.28	85213	1355	67.99	80.44	48.03	0.71	3.35
Hebei	24515.76	33969	7241	63.41	45.6	48.01	1.3	0.94
Shanxi	11237.55	31357	3593	65	49.68	53.04	1.76	1.15
Inner Mongolia	14359.88	57974	2482	67.86	56.61	49.45	1.41	0.94
Liaoning	22226.7	50760	4383	66.53	64.04	48.12	1.1	2.23
Jilin	10568.83	38460	2749	67.14	53.4	46.53	0.92	0.96
Heilongjiang	12582	32819	3834	68.58	56.49	41.6	1.04	1.19
Shanghai	19195.69	82560	2347	71.65	89.31	37.55	0.62	5.58
Jiangsu	49110.27	62290	7899	65.1	61.89	45.37	0.6	3.43
Zhejiang	32318.85	59249	5463	67.34	62.29	45.43	0.59	3.74
Anhui	15300.65	25659	5968	61.09	44.81	46.15	0.75	2.33
Fujian	17560.18	47377	3720	65.42	58.09	43.71	0.64	1.84
Jiangxi	11702.82	26150	4488	60.59	45.7	46.24	0.65	0.84
Shandong	45361.85	47335	9637	62.98	50.95	46.9	0.86	2.17
Henan	26931.03	28661	9388	60.2	40.57	51.8	0.9	1.33
Hubei	19632.26	34197	5758	64.57	51.82	43.49	0.91	1.37
Hunan	19669.56	29880	6596	61.19	45.1	41.3	0.89	1.19
Guangdong	53210.28	50807	10505	65.11	66.5	46.32	0.56	3.04
Guangxi	11720.87	25326	4645	58.52	41.81	41.39	0.8	1.11
Hainan	2522.66	28898	877	62.57	50.51	18.83	0.69	1.26
Chongqing	10011.37	34500	2919	61.12	55.02	46.85	0.95	0.97
Sichuan	21026.68	26133	8050	61.32	41.83	45.14	1	0.98
Guizhou	5701.84	16413	3469	57.01	34.97	32.08	1.71	0.96
Yunnan	8893.12	19265	4631	62.15	36.8	33.67	1.16	0.97
Shaanxi	12512.3	33464	3743	65.34	47.29	46.82	0.85	0.99
Gansu	5020.37	19595	2564	63.42	37.17	38.32	1.4	0.74
Qinghai	1670.44	29522	568	62.82	46.3	48.59	2.08	0.39
Ningxia	2102.21	33043	639	62.93	49.92	38.85	2.28	1.11
Xinjiang	6610.05	30087	2209	62.74	43.55	40.85	1.63	1.16

① Standardized treatment

First of all, it is necessary to process and standardize the original datain order to prevent different measurement units from influencing the results. The Standard Deviation method is applied to process the initial data. Set y_{ij} stands for the data after processing, the equation is

$$y_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j}, \quad i = 1, 2, \ldots, 30; \quad j = 1, 2, \ldots, 8, \tag{84.1}$$

Table 84.2 The standardized data of initial indicators

Region	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Beijing	−0.086	2.253	−0.914	1.899	2.467	−3.01	−1.271	2.896
Tianjin	−0.47	2.446	−1.163	1.174	2.038	0.679	−0.724	1.17
Hebei	0.556	−0.332	1.044	−0.198	−0.564	0.677	0.568	−0.645
Shanxi	−0.476	−0.473	−0.324	0.279	−0.26	1.311	1.574	−0.487
Inner Mongolia	−0.233	0.969	−0.741	1.135	0.258	0.858	0.808	−0.645
Liaoning	0.378	0.578	−0.028	0.737	0.813	0.691	0.13	0.326
Jilin	−0.528	−0.088	−0.641	0.92	0.018	0.49	−0.264	−0.63
Heilongjiang	−0.371	−0.394	−0.234	1.351	0.249	−0.131	−0.001	−0.457
Shanghai	0.143	2.302	−0.792	2.27	2.701	−0.642	−0.921	2.85
Jiangsu	2.467	1.203	1.29	0.309	0.653	0.344	−0.964	1.231
Zhejiang	1.162	1.039	0.377	0.979	0.682	0.352	−0.986	1.464
Anhui	−0.16	−0.782	0.566	−0.893	−0.623	0.442	−0.636	0.402
Fujian	0.015	0.395	−0.277	0.404	0.369	0.135	−0.877	0.033
Jiangxi	−0.44	−0.755	0.011	−1.042	−0.557	0.454	−0.855	−0.721
Shandong	2.176	0.393	1.942	−0.326	−0.165	0.537	−0.395	0.281
Henan	0.744	−0.619	1.849	−1.159	−0.94	1.155	−0.308	−0.352
Hubei	0.176	−0.319	0.487	0.15	−0.1	0.107	−0.286	−0.321
Hunan	0.179	−0.553	0.802	−0.863	−0.602	−0.169	−0.33	−0.457
Guangdong	2.786	0.581	2.267	0.312	0.997	0.464	−1.052	0.937
Guangxi	−0.438	−0.8	0.07	−1.662	−0.847	−0.158	−0.527	−0.517
Hainan	−1.153	−0.606	−1.343	−0.449	−0.198	−3.001	−0.767	−0.404
Chongqing	−0.571	−0.303	−0.577	−0.884	0.139	0.531	−0.198	−0.623
Sichuan	0.285	−0.756	1.347	−0.824	−0.846	0.315	−0.089	−0.615
Guizhou	−0.906	−1.283	−0.371	−2.115	−1.358	−1.331	1.465	−0.63
Yunnan	−0.658	−1.129	0.065	−0.575	−1.222	−1.131	0.261	−0.623
Shaanxi	−0.377	−0.359	−0.268	0.38	−0.438	0.527	−0.417	−0.608
Gansu	−0.959	−1.111	−0.71	−0.195	−1.194	−0.544	0.786	−0.796
Qinghai	−1.219	−0.573	−1.459	−0.374	−0.512	0.75	2.275	−1.06
Ningxia	−1.186	−0.382	−1.432	−0.341	−0.242	−0.478	2.712	−0.517
Xinjiang	−0.835	−0.542	−0.843	−0.398	−0.718	−0.226	1.29	−0.48

where $\bar{x}_j$ is sample average, $\bar{x}_j = \frac{1}{n}\sum_{i=1}^{n} x_{ij}$ and, S_j is sample standard deviation, and $S_j = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_{ij} - \bar{x}_j)^2}$. The standardized data is shown in Table 84.2.

②Correlation matrix R

The calculation formula of r_{ij} is

$$r_{ij} = \frac{1}{p-1}\sum_{k=1}^{p} y_{ik}y_{jk}, \quad i, j = 1, 2, \ldots, 30; \quad p = 8 \tag{84.2}$$

Table 84.3 The correlation matrix

Indicator	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
X_1	1							
X_2	0.381	1						
X_3	0.833	−0.092	1					
X_4	0.17	0.798	−0.249	1				
X_5	0.288	0.949	−0.172	0.829	1			
X_6	0.306	−0.047	0.378	−0.044	−0.145	1		
X_7	−0.509	−0.447	−0.392	−0.28	−0.463	0.134	1	
X_8	0.441	0.855	0.057	0.643	0.866	−0.28	−0.559	1

Table 84.4 The eigenvalues and variance contribution

Component	Initial eigenvalues		
	Total	% of Variance	Cumulative %
1	3.979	49.743	49.743
2	2.184	27.295	77.038
3	1.029	12.86	89.898
4	0.405	5.066	94.963
5	0.233	2.918	97.881
6	0.091	1.139	99.02
7	0.042	0.53	99.551
8	0.036	0.449	100

After calculation, we get the correlation matrix R shown in Table 84.3.

③ Eigenvalues of R

By Using the Factor Section of SPSS to perform PCA, we can get the eigenvalues and variance contribution of the correlation matrix R, shown in Table 84.4. According to the basic rules of principle component analysis, 3 principle components are selected, and the cumulative variance contribution rate is 88.309 %, which meet the requirement of greater than 85 %.

④ Component Matrix

The component matrix of the 3 principle components is shown as Table 84.5.

The eigenvectors, as shown in Table 84.6, are calculated based on the component matrix and eigenvalues Set Z_1, Z_2, Z_3 represent the 3 principle components, then according to the eigenvector matrix, we have

$$
\begin{aligned}
Z_1 =& 0.257X_1 + 0.473X_2 + 0.04X_3 + 0.401X_4 + 0.473X_5 - 0.063X_6 - 0.322X_7 + 0.465X_8.\\
Z_2 =& 0.546X_1 - 0.095X_2 + 0.655X_3 - 0.211X_4 - 0.161X_5 + 0.363X_6 - 0.245X_7 - 0.036X_8,\\
Z_3 =& 0.004X_1 + 0.184X_2 - 0.118X_3 + 0.324X_4 + 0.117X_5 + 0.78X_6 + 0.446X_7 - 0.165X_8.
\end{aligned}
$$

Table 84.5 The component matrix

	Component		
	1	2	3
X_1	0.514	0.807	0.005
X_2	0.943	−0.14	0.187
X_3	0.079	0.968	−0.12
X_4	0.801	−0.312	0.328
X_5	0.944	−0.238	0.119
X_6	−0.126	0.536	0.791
X_7	−0.641	−0.362	0.452
X_8	0.928	−0.054	−0.167

Table 84.6 The eigenvector matrix

	Z_1	Z_2	Z_3
X_1	0.257	0.546	0.004
X_2	0.473	−0.095	0.184
X_3	0.04	0.655	−0.118
X_4	0.401	−0.211	0.324
X_5	0.473	−0.161	0.117
X_6	−0.063	0.363	0.78
X_7	−0.322	−0.245	0.446
X_8	0.465	−0.036	−0.165

So we have 3 new comprehensive indicators which can express the meaning of the 8 initial indicators. Based on the standardized data in Table 84.7, we can calculate new indicator values of each province, shown in Table 84.7.

84.4.2 *Weight Calculation*

In the section, the Entropy Method is applied to calculate the weight values of new indicators. Before that, nonnegative treatment is used to eliminate negative values in Table 84.7. The data processing means is as follows,

$$z'_{ij} = [(z_{ij} - \min(z_j))/(\max(z_j) - \min(z_j)]\alpha + (1 - \alpha), \tag{84.3}$$

Table 84.7 The new indicators

Region	Z_1	Z_2	Z_3
Beijing	4.881	−2.543	−1.967
Tianjin	3.159	−1.445	1.218
Hebei	−0.844	1.281	0.576
Shanxi	−1.186	−0.336	1.814
Inner Mongolia	0.332	−0.849	1.799
Liaoning	1.116	0.054	0.988
Jilin	−0.064	−0.632	0.726
Heilongjiang	0.165	−0.674	0.393
Shanghai	4.944	−1.683	0.187
Jiangsu	2.549	2.224	−0.109
Zhejiang	2.496	0.783	0.142
Anhui	−0.677	0.948	−0.579
Fujian	0.805	−0.093	−0.012
Jiangxi	−1.24	0.548	−0.453
Shandong	0.838	2.8	−0.077
Henan	−1.074	2.579	0.007
Hubei	−0.137	0.55	−0.07
Hunan	−0.91	0.991	−0.749
Guangdong	2.423	3.117	−0.194
Guangxi	−1.616	0.46	−1.068
Hainan	−0.662	−2.212	−2.742
Chongqing	−0.861	−0.233	0.169
Sichuan	−1.238	1.578	−0.355
Guizhou	−3.026	−0.77	−1.321
Yunnan	−1.812	−0.343	−1.21
Shaanxi	−0.514	−0.042	0.361
Gansu	−2.032	−1.011	−0.27
Qinghai	−2.308	−1.652	1.655
Ningxia	−1.878	−2.258	0.877
Xinjiang	−1.628	−1.138	0.262

where $\max(z_j)$ and $\min(z_j)$ are the maximum and minimum value in jth column, and α is equal to 0.5. The values of new indicators by nonnegative treatment are shown in Table 84.8. Then the Entropy Method is applied to calculate the weights of the new indicators, firstly we can get Table 84.9 by normalizing Table 84.8 to calculate the weight of each indicator, which is (0.370, 0.316, 0.314).

Table 84.8 The new indicators after nonnegative treatment

Region	Z_1	Z_2	Z_3
Beijing	0.996	0.5	0.585
Tianjin	0.888	0.597	0.935
Hebei	0.637	0.838	0.864
Shanxi	0.615	0.695	1
Inner Mongolia	0.711	0.65	0.998
Liaoning	0.76	0.729	0.909
Jilin	0.686	0.669	0.881
Heilongjiang	0.7	0.665	0.844
Shanghai	1	0.576	0.821
Jiangsu	0.85	0.921	0.789
Zhejiang	0.846	0.794	0.817
Anhui	0.647	0.808	0.737
Fujian	0.74	0.716	0.8
Jiangxi	0.612	0.773	0.751
Shandong	0.742	0.972	0.792
Henan	0.622	0.952	0.802
Hubei	0.681	0.773	0.793
Hunan	0.633	0.812	0.719
Guangdong	0.842	1	0.78
Guangxi	0.588	0.765	0.684
Hainan	0.648	0.529	0.5
Chongqing	0.636	0.704	0.819
Sichuan	0.612	0.864	0.762
Guizhou	0.5	0.657	0.656
Yunnan	0.576	0.694	0.668
Shaanxi	0.658	0.721	0.841
Gansu	0.562	0.635	0.771
Qinghai	0.545	0.579	0.983
Ningxia	0.572	0.525	0.897
Xinjiang	0.588	0.624	0.83

84.4.3 Proportion Allocation

On the basis of Table 84.9 and the weight of each indicator, we can calculate the comprehensive evaluation index of carbon dioxide emissions in 2011, shown in Table 84.10. Similarly as the calculation of 2011 comprehensive evaluation index,

Table 84.9 The normalized matrix

0.048	0.023	0.024
0.043	0.027	0.039
0.031	0.039	0.036
0.03	0.032	0.042
0.034	0.03	0.042
0.037	0.034	0.038
0.033	0.031	0.037
0.034	0.031	0.035
0.048	0.026	0.034
0.041	0.042	0.033
0.041	0.037	0.034
0.031	0.037	0.031
0.036	0.033	0.033
0.03	0.036	0.031
0.036	0.045	0.033
0.03	0.044	0.033
0.033	0.036	0.033
0.031	0.037	0.03
0.041	0.046	0.032
0.028	0.035	0.028
0.031	0.024	0.021
0.031	0.032	0.034
0.03	0.04	0.032
0.024	0.03	0.027
0.028	0.032	0.028
0.032	0.033	0.035
0.027	0.029	0.032
0.026	0.027	0.041
0.028	0.024	0.037
0.028	0.029	0.035

we can get the indexes of 2009 and 2010, as shown in Fig. 84.2. To obtain the weighted average of each province, different weights are given to data of 2009, 2010 and 2011, to predict the future comprehensive index which will be taken as the rule of decomposing the target of carbon dioxide emissions. The weights of 2009, 2010 and 2011 are 1, 3 and 5, as newer data can reflect the situation in the future better. The

Table 84.10 The comprehensive index and weighted average

Region	2009	2010	2011	Weighted average
Beijing	0.728	0.734	0.707	0.808
Tianjin	0.858	0.811	0.787	0.903
Hebei	0.761	0.763	0.769	0.862
Shanxi	0.75	0.734	0.738	0.83
Inner Mongolia	0.799	0.778	0.756	0.864
Liaoning	0.826	0.81	0.784	0.897
Jilin	0.8	0.77	0.726	0.843
Heilongjiang	0.801	0.769	0.721	0.839
Shanghai	0.732	0.798	0.794	0.887
Jiangsu	0.82	0.857	0.863	0.963
Zhejiang	0.79	0.819	0.819	0.918
Anhui	0.664	0.717	0.73	0.808
Fujian	0.721	0.748	0.745	0.836
Jiangxi	0.647	0.689	0.707	0.781
Shandong	0.824	0.84	0.843	0.945
Henan	0.736	0.779	0.792	0.879
Hubei	0.741	0.753	0.743	0.839
Hunan	0.669	0.699	0.722	0.797
Guangdong	0.797	0.866	0.888	0.979
Guangxi	0.614	0.673	0.679	0.754
Hainan	0.555	0.574	0.567	0.639
Chongqing	0.676	0.696	0.706	0.787
Sichuan	0.66	0.727	0.745	0.821
Guizhou	0.611	0.6	0.598	0.675
Yunnan	0.598	0.644	0.643	0.718
Shaanxi	0.736	0.74	0.726	0.823
Gansu	0.675	0.662	0.64	0.733
Qinghai	0.675	0.66	0.663	0.746
Ningxia	0.656	0.626	0.632	0.712
Xinjiang	0.644	0.66	0.66	0.741

distributive outcome, which is obtained by the weighted average of comprehensive indexes, as shown in Fig. 84.3, is in perfect accordance with the actual situation in China. In the practical analysis, more data should be taken into calculation. In addition, the closer data reflects the future better, the newer data will obtain much better results, so timely data statistics should be attached much greater importance.

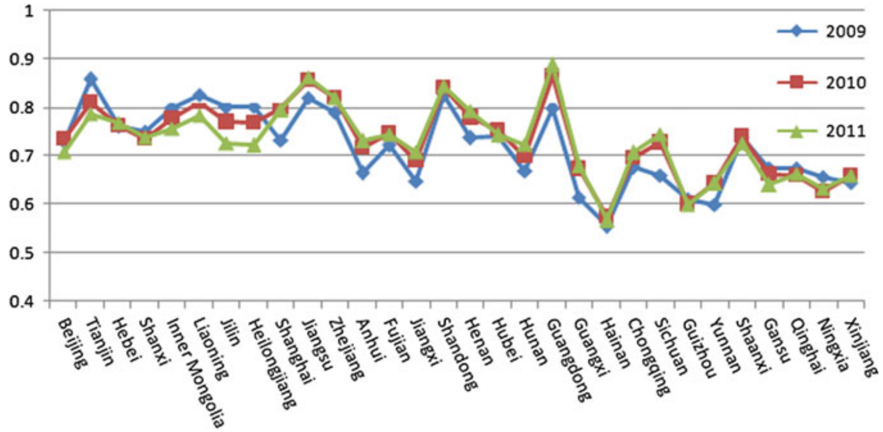


Fig. 84.2 The comprehensive index of 2009−2011

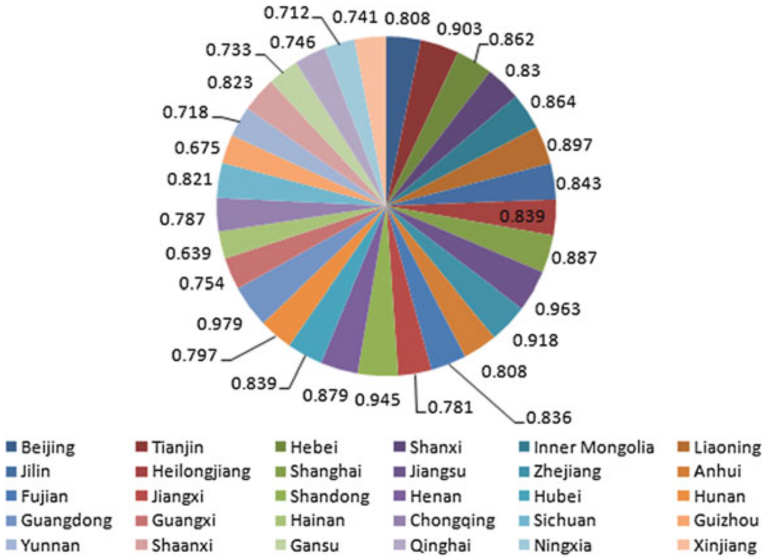


Fig. 84.3 The distributive outcome

84.5 Conclusion

Reducing CO_2 emissions is one of the important issues of common concern to the international community. The missions must be decomposed in accordance with the regions in order to smoothly achieve the target of reducing carbon emissions. Based on the analysis of current situation of carbon emissions in China, this paper puts forward the multi-factor multi-region decomposition method. Firstly, this method lists the various factors which affect CO_2 emissions in China, and puts forward a series of initial indicators to measure a variety of factors. Because there is a strong correlation among the great deal of indicators, principal component analysis is carried out on the initial indicators to get three new indicators to explain the original initial indicators. Secondly, entropy method is used to weight new indicators, then the comprehensive evaluation indexes of various provinces and cities are obtained. Finally, on the basis of comparing comprehensive evaluation indexes in each year, decomposition rate of carbon emissions task is calculated by weighted average method.

Through the analysis of empirical results we can see that the effect of this method is ideal. But empirical data used in this article is only from 2009 to 2011, data of more years can be considered in further calculation. And further work should be focused on the establishment of indicator system and prediction of the future trend.

References

1. Alcantara V, Duarte R (2004) Comparison of energy intensities in european union countries. results of a structural decomposition analysis. Energy Policy 32(2):177–189
2. Ang BW, Liu F, Chew EP (2003) Perfect decomposition techniques in energy and environmental analysis. Energy Policy 31(14):1561–1566
3. Carter AP (1970) Structual change in the American economy. Harvard University Press, Massachusetts
4. Child D (2006) The essentials of factor analysis 3rd edn. Bloomsbury Academic Press, Bloomsburry
5. Chen XK, Guo J (2000) China economic structure and sda model. J Syst Eng 9(2):142–148
6. Dalkey N, Helmer O (1963) An experimental application of the Delphi method to the use of experts. Manage Sci 9(3):458–467
7. De Nooij M, van der Kruk R, Van Soest DP (2003) International comparisons of domestic energy consumption. Energy Econ 25(4):359–373
8. Hoekstra R, Van den Bergh JC (2003) Comparing structural decomposition analysis and index. Energy Econ 25(1):39–64
9. Jolliffe I (2002) Principal component analysis, 2nd edn. Wiley Online Library
10. Kagawa S, Inamura H (2004) A spatial structural decomposition analysis of chinese and Japanese energy demand: 1985–1990. Econ Syst Res 16(3):279–299
11. Malla S (2009) CO_2 emissions from electricity generation in seven asia-pacific and north american countries: A decomposition analysis. Energy Policy 37(1):1–9
12. Park SH, Dissmann B, Nam KY (1993) A cross-country decomposition analysis of manufacturing energy consumption. Energy 18(8):843–858
13. Rubinstein RY, Kroese DP (2004) The cross-entropy method. a unified approach to combinatorial optimization, Monte-carlo simulation and neural computation. Springer, Berlin
14. Saaty TL (1990) How to make a decision: the analytic hierarchy process. Eur J Oper Res 48(1):9–26
15. Shrestha RM, Timilsina GR (1996) Factors affecting CO_2 intensities of power sector in asia: a divisia decomposition analysis. Energy Econ 18(4):283–293
16. Shrestha RM, Anandarajah G, Liyanage MH (2009) Factors affecting CO_2 emission from the power sector of selected countries in asia and the pacific. Energy Policy 37(6):2375–2384

17. Skolka J (1989) Input-output structural decomposition analysis for austria. J Policy Model 11(1):45–66
18. Steenhof PA, Weber CJ (2011) An assessment of factors impacting canada's electricity sector's ghg emissions. Energy Policy 39(7):4089–4096
19. Sun J (1998) Changes in energy consumption and energy intensity: a complete decomposition model. Energy Econ 20(1):85–100
20. Zhang M, Liu X, Wang W, Zhou M (2013a) Decomposition analysis of CO_2 emissions from electricity generation in China. Energy Policy 52:159–165

Chapter 85
Parallel Machine Scheduling Problem of Flexible Maintenance Activities with Fuzzy Random Time Windows

Ling Nie

Abstract In this paper, a scheduling problem on parallel machines subject to fuzzy random time windows was studied. The main purpose was to meet demands of both production scheduling and maintenance planning. Then, there were two objectives considered, minimizing the makespan and maximizing average timeliness level. First, a fuzzy random variable for maintenance time windows was considered, and this model was then transformed using the expected value. Then, an instance of the algorithm was demonstrated to illustrate the applicability of the proposed approach and the results obtained were highly favourable.

Keywords Parallel machine scheduling problem · Fuzzy random · Maintenance · Timeless level

85.1 Introduction

As production scheduling is one of the key factors that affects the manufacturing system performance, a great amount of production scheduling models have been studied and designed to solve this problem [12]. Parallel machine scheduling problems are among the most important problems in scheduling literature, since these are not only a factor in most manufacturing environments, but also have been widely used in information systems, [4, 8, 14, 19].

In practical production process of the manufacturing enterprise system, machines will be worn and corroded with the continuous increase of service time. If machines are not maintained or replaced in time, they will degrade rapidly. Once they are totally broken, the enterprise has to pay extra high outage cost and increase total manufacturing cost. Furthermore, the enterprise may need to adjust the operation plan and assign tasks again. Under these circumstances, the sipping time and the

L. Nie (✉)
School of Tourism, Economic and Management, Chengdu University,
Chengdu 610106, People's Republic of China
e-mail: nieling@cdu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_85

delivery time is delayed, and thus decreasing the customers satisfaction degree, and affecting the future development of the enterprise negatively. In the literature, it is often assumed that the maintenance duration is constant, see [1, 16, 18].

With rapid development of technology and sciences, the manufacturing is entering a Post Mass Production stage, in which different customers have different needs for product characterization and personalization. The developing trend of product characterization and personalization motives the products to update constantly and more complex product structures are required. As a consequence, the accurate job processing time is hard to obtain in the new product scheduling. To date, much research has been devoted to the problems of parallel machine scheduling under deterministic environments, such as [4, 8, 14, 19]. However, a small number of studies have been published for uncertain parameters. Fuzzy random variables represent a well-formalized concept underlying many recent probabilistic and statistical studies involving data obtained from a random experiment when these data are assumed to be fuzzy set valued [3]. It has been applied in many fields, see [9, 17]. However there are few researchers who have considered the fuzzy random factors in parallel machine scheduling problem. Peng and Liu [11] examined the problem of parallel-machines scheduling with fuzzy processing times.

According to the previous background introduction, this paper studies the machine scheduling problem with fuzzy random time windows and maintenance based on the current related research the fuzzy uncertainty theory, the multi-objective optimization theory, and the machine scheduling programming theory.

85.2 Modelling

85.2.1 Assumptions and Notations

Assume that a set of n jobs ($J = \{J_1, J_2, \ldots, J_n\}$) need to be processed on a set of m machines ($M = \{M_1, M_2, \ldots, M_n\}$), see Fig. 85.1. There are some assumptions adopted before the construction of the model.

(1) All jobs are available at time zero, i.e., $t = 0$.
(2) Preempting one job for another is not permitted.
(3) Maintenance should be scheduled between jobs, that is to say, all maintenance task must be completed before the last job.
(4) The preventive maintenance indices are also the preventive maintenance sequence, that is, PM_{ij} is the ith preventive maintenance on the machine M_j.

The following notations are used to describe parallel machine problem of flexible maintenance activities under with fuzzy random time windows.

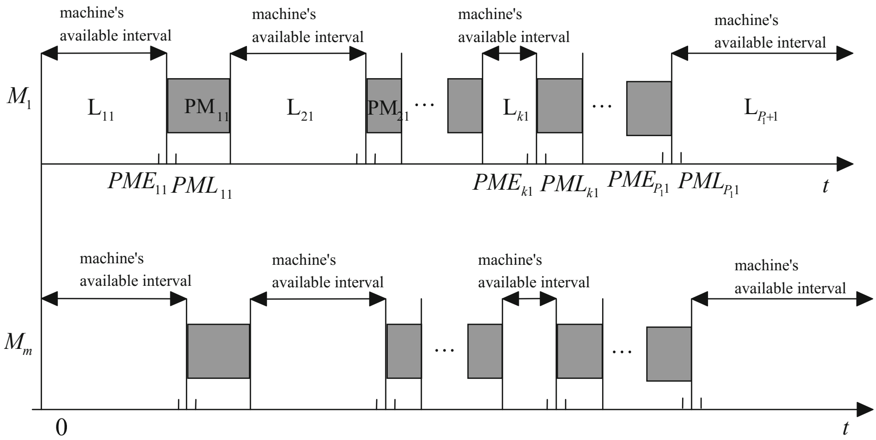


Fig. 85.1 Parallel machine scheduling problem with maintenance

Indices

i : index of jobs, $i = 1, 2, \ldots, n$;
j : index of maintenance tasks, $j = 1, 2, \ldots, m$;

Certain Parameters

n	: number of jobs to be scheduled;
m	: number of machines;
P_j	: Number of maintenance activities on machine M_j, and $P_1 + \cdots + P_m = P$;
PME_{kj}	: earliest time for the kth maintenance activity on machine M_j;
PME_{kj}	: latest time for the kth maintenance activity on machine M_j;
p_i	: the processing time for job J_i for processing at time zero;
a_{kj}	: the maintenance time for the kth maintenance activity on machine M_j;
t_{kj}	: the starting time for kth maintenance activity on machine M_j;
CPM_{kj}	: the completion time for kth maintenance activity on machine M_j;
CJ_i	: the completion time for job J_i;
$J_{[ij]}$	: the order of jobs in the sequence on machine M_j;
$P_{[ij]}$	: the processing time of the ith job in the sequence on machine M_j;
$P_{[ij]}$	: the completion time of the ith job in the sequence on machine M_j;
$T(t)$	: the timeliness level;

Uncertain Parameters

PME^e_{kj} : Endurable earliest time for the kth maintenance activity on machine M_j;
PML^e_{kj} : Endurable latest time for the kth maintenance activity on machine M_j;

Decision Variables

X_{ihj} : the job sequencing decision variable on machine M_j;
Y_{ikj} : the integrated maintenance activity decision variable on machine M_j;

Here

$$x_{ihj} = \begin{cases} 1, & \text{if the ith job performed on machine } \mathrm{M_j} \text{ is job } \mathrm{J}_h; \\ 0, & \text{otherwise,} \end{cases}$$

where $i, h = 1, 2, \ldots, n$, $j = 1, 2, \ldots, m$. Based on the decision variable X_{ihj}, the processing time of the ith job on machine M_j can be deduced as

$$p_{[ij]} = \sum_{h=1}^{n} p_h x_{ihj}, \; C_{[ij]} = \sum_{k=1}^{n} p_{[kj]},$$

and

$$y_{ikj} = \begin{cases} 1, & \text{if the kth maintenance activity} \\ & \text{is performed prior to the ith job on machine } \mathrm{M_j}; \\ 0, & \text{otherwise.} \end{cases}$$

85.2.2 Objective Functions

Since the maintenance activities will take time which can be used for processing jobs, the makespan will be longer. However, delaying or canceling the maintenance activities for the processing jobs may increase the risk of machine failure. In consideration of all the condition, this parallel machine scheduling problem proposed an integrated maintenance planning job scheduling model. There are two main objectives, one is for maintenance planning, and the other is for job scheduling.

The first objective is to minimize the makespan, which can be described as follows:

$$\min f_1 = C_{\max} = \max_{1 \leqslant j \leqslant m} \max_{1 \leqslant i \leqslant n} .C_{[ij]}. \tag{85.1}$$

To better interpret the completion time for each job, it has some steps to analysis the factors which influence the completion time. For the first job on machine M_j, it should consider the completion time of the previous jobs, the processing time of this job and the previous maintenance conditions. Then,

$$C_{[1j]} = \sum_{h=1}^{n} p_h x_{1hj} + y_{1kj}(t_{kj} + a_{kj}). \tag{85.2}$$

And for the second job on machine M_j, the completion time $C_{[2j]}$ can be depicted as

$$C_{[2j]} = \sum_{h=I}^{n} p_h x_{2hj} + \sum_{l=1}^{2} y_{lkj}(t_{kj} + a_{kj}), \tag{85.3}$$

where $I = \{1, 2, \ldots, n\} \cap \overline{Q}_{1j}$, $Q_{1j} = \{J_{[1j]}\}$, then for the ith job on machine M_j, the completion time $C_{[ij]}$ can be depicted as

$$C_{[ij]} = \sum_{h=I}^{n} p_h x_{ihj} + \sum_{l=1}^{i} y_{lkj}(t_{kj} + a_{kj}), \tag{85.4}$$

where $I = \{1, 2, \ldots, n\} \cap \overline{Q}_{1j}$, $Q_{1j} = \{J_{[1j]}, \ldots, J_{[i-1,j]}\}$.

The second objective is to measure and maximize the timeliness level, which can be described as follows:

$$\max f_2 = \frac{1}{P} \sum_{l=1}^{P} T(t_l), \tag{85.5}$$

where

$$T(t) = \begin{cases} 0, t < \overline{\tilde{PME}}^e \\ \frac{t - \overline{\tilde{PME}}^e}{PME - \overline{\tilde{PME}}^e}, \overline{\tilde{PME}}^e \le t < PME \\ 1, PME \le t \le PML \\ \frac{\overline{\tilde{PML}}^e - t}{\overline{\tilde{PML}}^e - PML}, PML \le t \le \overline{\tilde{PML}}^e \\ 0, t \ge \overline{\tilde{PML}}^e \end{cases} \tag{85.6}$$

The time windows are fuzzy random variables; i.e., $[\overline{\tilde{PME}}^e, \overline{\tilde{PML}}^e]$. As is generally known, it is very difficult to obtain an optimal solution directly as fuzzy random variables are very imprecise. According to the method proposed in [10], the $[\overline{\tilde{PME}}^e, \overline{\tilde{PML}}^e]$ can be transferred into $(E^f[E[\overline{\tilde{PME}}^e]], E^f[E[\overline{\tilde{PML}}^e]])$. Based on the definitions for $E^f[E[\overline{\tilde{PME}}^e]]$ and $E^f[E[\overline{\tilde{PML}}^e]]$, the timeliness level can be described using a fuzzy membership function as in:

$$T(t) = \begin{cases} 0,\ t < E^f[E[\overline{\tilde{PME}}^e]] \\ \frac{t - E^f[E[\overline{\tilde{PME}}^e]]}{PME - E^f[E[\overline{\tilde{PME}}^e]]}, E^f[E[\overline{\tilde{PME}}^e]] \leqslant t < PME \\ 1\ PME \leqslant t \leqslant PML \\ \frac{E^f[E[\overline{\tilde{PML}}^e]] - t}{E^f[E[\overline{\tilde{PML}}^e]] - PML}, PML \leqslant t \leqslant E^f[E[\overline{\tilde{PML}}^e]] \\ 0,\ t \geqslant E^f[E[\overline{\tilde{PML}}^e]]. \end{cases} \tag{85.7}$$

85.2.3 Constraints

Suppose that the $(i-1)$th job is the last processing job before the kth maintenance activity on machine M_j; that is, the kth maintenance activity is conducted between the $(i-1)$th job and the ith job on machine M_j. If the $(i-1)$th job is completed earlier before the worker is prepared, the machine has to wait; and if it is completed later than PME^e_{kj} and earlier than PML^e_{kj}, the kth maintenance activity can be started immediately, that is,

$$t_{kj} \geqslant \max\{E^f[E[\overline{\tilde{PME}}^e_{kj}]], y_{ikj}C_{[i-1,j]}\}, k = 1, \ldots, P_j, j = 1, 2, \ldots, m, \tag{85.8}$$

$$t_{kj} \leqslant E^f[E[\overline{\tilde{PML}}^e_{kj}]], k = 1, \ldots, P_j, j = 1, 2, \ldots, m, \tag{85.9}$$

where E^f in $E^f[E[\overline{\tilde{PME}}^e_{kj}]]$ and $E^f[E[\overline{\tilde{PME}}^e_{kj}]]$ turns the fuzzy random variables into fuzzy variables as in [6], and E is used to transform the fuzzy variables into deterministic values.

In the scheduling, it is necessary to ensure that the machine receives one job only one time, and each job is assigned to one machine in the schedule, respectively. Then,

$$\begin{aligned} &\sum_{h=1}^{n} x_{ihj} = 1, i = 1, \ldots, n; j = 1, 2, \ldots, m, \\ &\sum_{i=1}^{n} x_{ihj} = 1, h = 1, \ldots, n; j = 1, 2, \ldots, m. \end{aligned} \tag{85.10}$$

Each maintenance activity can be served by one person and only one time, and then,

$$\begin{aligned} &\sum_{i=1}^{n} y_{ikj} = 1, k = 1, \ldots, P_j; j = 1, 2, \ldots, m, \\ &\sum_{k=1}^{P_j} y_{ikj} \leqslant 1, i = 1, \ldots, n; j = 1, 2, \ldots, m. \end{aligned} \tag{85.11}$$

85.2.4 Global Modelling

From the discussions above, and by integration of Eqs. (85.1)–(85.11), the mathematical model can be stated as follows:

$$\min f_1 = C_{\max} = \max_{1 \leqslant j \leqslant m} \max_{1 \leqslant i \leqslant n} C_{[ij]},$$

$$\max f_2 = \frac{1}{P} \sum_{l=1}^{P} T(t_l).$$

$$s.t. \begin{cases} \sum_{h=1}^{n} x_{ihj} = 1, i = 1, \ldots, n; j = 1, 2, \ldots, m \\ \sum_{i=1}^{n} x_{ihj} = 1, h = 1, \ldots, n; j = 1, 2, \ldots, m \\ t_{kj} \geqslant \max\{E^f[E[\overline{\tilde{PME}}^{e}_{kj}]], y_{ikj} C_{[i-1,j]}\}, k = 1, \ldots, m \\ t_{kj} \leqslant E^f[E[\overline{\tilde{PML}}^{e}_{kj}]] \\ \sum_{i=1}^{n} y_{ikj} = 1, k = 1, \ldots, P_j \\ \sum_{k=1}^{n} y_{ikj} \leqslant 1, i = 1, \ldots, n \\ x_{ihj} \in \{0, 1\}, h, i = 1, \ldots, n; j = 1, 2, \ldots, m \\ y_{ikj} \in \{0, 1\}, i = 1, \ldots, n; k = 1, \ldots, P_j; j = 1, 2, \ldots, m \end{cases} \tag{85.12}$$

This study of parallel machine scheduling problem of maintenance with fuzzy random time windows is meaningful and can be widely applied to industries in such area as transportation semiconductor manufacturing and power generation. The main contribution of this research is the conversion of the fuzzy random variables into deterministic values, where the maximization of the total timeliness level and minimization the makespan are simultaneously considered.

85.3 GLNPSO-LPT Algorithm

The Particle Swarm Optimization (PSO) algorithm introduced by Kennedy and Eberhart in 1995 [5], is one of the most important swarm intelligence paradigms. The idea comes from the research, modeling and simulation of the behavior of swarms of insects in nature.

85.3.1 Decoding Method

In this paper, it will adopt two different ways to encode the job sequence and the maintenance activity sequence. For job sequence, it takes Real-value coding. Considering the distribution between different devices, it adds $-1(-m+1)$ as an identifier, to divide the different machines. And for the maintenance activity sequence, it adopts Binary coding. An example is given below to elucidate the coding method. Assume that there are nine jobs $(J_1, J_2, \ldots, J_9)$, three parallel machines (M_1, M_2, M_3) and three maintenance activity $PM_{11}, PM_{12}, PM_{13}$.

4	7	8	-1	5	1	3	-2	9	6	2
0	0	1	0	0	1	0	0	0	0	1

Fig. 85.2 An example for job sequence and maintenance activity sequence

Figure 85.2 shows a set of chromosome coding examples. The first line means job sequence, and the second line shows the maintenance activity sequence. For this solution, J_4, J_7, J_8 are scheduled on Machine M_1 and PM_{11} is scheduled before J_8, J_5, J_1, J_3 are scheduled on Machine M_2 and PM_{12} is scheduled before J_1, J_9, J_6, J_2 are scheduled on Machine M_3 and PM_{13} is scheduled before J_2.

85.3.2 Swarm Initialization

As mentioned, two swarms A and B are generated using different approaches, and after a certain number of iterations some particles are exchanged to avoid the particle becoming trapped. The P time windows for the maintenance activities divide the time shaft into $P + m$ machine available intervals. If only the objective of the makespan without the maintenance activities is considered, then the optimal scheduling is be determined by following the rule of the longest processing time first (LPT) [13]. When considering these actions with maintenance activities, the problem is similar to the bin packing problem [2]. Therefore, it is suitable to use the First Fit rule to deal with the initialized swarm. Therefore, Swarm A is considered to be randomly initialized, and the particle in Swarm B is initialized as follows:

Step 1 Arrange all jobs according to the LPT rule to form a sequencing priority list.
Step 2 Set the $P + m$ machine's available intervals as.

$$
\begin{aligned}
M_1 : L_{11} &= \left[0, \frac{PME_{11} + PML_{11}}{2}\right], \\
L_{21} &= \left[\frac{PME_{11} + PML_{11}}{2} + t_{11}, \frac{PME_{21} + PML_{21}}{2}\right], \ldots, \\
L_{k1} &= \left[\frac{PME_{(k-1)1} + PML_{(k-1)1}}{2} + t_{k1}, \frac{PME_{k1} + PML_{k1}}{2}\right], \ldots, L_{(P_1+1)1} \\
&= \left[\frac{PME_{P_1 1} + PML_{P_1 1}}{2} + t_{P_1 1}, \infty\right], \\
M_2 : L_{12} &= \left[0, \frac{PME_{12} + PML_{12}}{2}\right], \\
L_{22} &= \left[\frac{PME_{12} + PML_{12}}{2} + t_{12}, \frac{PME_{22} + PML_{22}}{2}\right], \ldots,
\end{aligned}
$$

$$L_{k2} = \left[\frac{PME_{(k-1)2} + PML_{(k-1)2}}{2} + t_{k2}, \frac{PME_{k2} + PML_{k2}}{2}\right], \ldots, L_{(P_2+1)2}$$
$$= \left[\frac{PME_{P_2 2} + PML_{P_2 2}}{2} + t_{P_2 2}, \infty\right],$$
$$\ldots$$

$$M_m : L_{1m} = \left[0, \frac{PME_{1m} + PML_{1m}}{2}\right],$$
$$L_{2m} = \left[\frac{PME_{1m} + PML_{1m}}{2} + t_{1m}, \frac{PME_{2m} + PML_{2m}}{2}\right], \ldots,$$
$$L_{km} = \left[\frac{PME_{(k-1)m} + PML_{(k-1)m}}{2} + t_{km}, \frac{PME_{km} + PML_{km}}{2}\right], \ldots, L_{(P_m+1)m}$$
$$= \left[\frac{PME_{P_m m} + PML_{P_m m}}{2} + t_{P_m m}, \infty\right].$$

Arrange these $P + m$ machine's available intervals as $L_{11}, L_{12}, \ldots, L_{1m}$ (the first column), $L_{21}, L_{22}, \ldots, L_{2m}$ (the second column), …, $L_{(p_1+1)}, \ldots,$ $L_{(p_m+1)}$. Assign the first job $J_{[1]}$ to the first available interval L_{11}. If one of $L_{12}, \ldots, L_{1m}$ (set as L_{1j}) can hold $J_{[2]}$, then put $J_{[2]}$ into L_{1j}. Otherwise, considering $L_{21}, L_{22}, \ldots, L_{2m}$ until one available interval can hold it. Generally speaking, if $J_{[t]}$ is assigned to the lth column, and there are surplus space in the lth column, then put $J_{[t+1]}$ into the lth column, otherwise, put $J_{[t+1]}$ into the $(l+1)$th column.

Step 3 Repeat Steps 2 until all jobs are arranged.

85.3.3 The Fitness Value Function

Since two objectives are considered in this paper; the minimization the makespan, and the maximization of the average timeliness level, the utility function or weighted function proposed by Li [7] is applied, and is used to convert the multi-objective problem into a single-objective problem. Objective f_1 is a minimization problem and f_2 is a maximization problem, then, the fitness value function in Model (85.12) is given as

$$\text{Fitness} = a_1 C_{\max} + \frac{-a_2}{m} \sum_{k=1}^{m} T_k(t_k), \tag{85.13}$$

where a_1 and a_2 are the penalty coefficients defined according to the practical situation, and $a_1 + a_2 = 1$.

85.3.4 Particle Velocity and Position

In this paper, the position and velocity of each particle are updated by the following equations which is called GLNPSO proposed by Veeramachaneni [15]:

$$\begin{aligned}\upsilon_{sd}(\tau+1) = \omega(\tau)\upsilon_{sd}(\tau) + c_p r_p[\mathrm{PBest}_{sd}(\tau) \\ - P_{sd}(\tau)] + c_g r_g[\mathrm{GBest}_{sd}(\tau) - P_{sd}(\tau)] + c_l r_l[\mathrm{LBest}_{sd}(\tau) - P_{sd}(\tau)] \\ + c_n r_n[\mathrm{NBest}_{sd}(\tau) - P_{sd}(\tau)],\end{aligned} \quad (85.14)$$

where s is the particle index, $s = 1, 2, \ldots, S$ (S is the population size);

τ is the iteration index, $\tau = 1, 2, \ldots, N$, (N is the iteration limit);

$\upsilon_{sd}(\tau)$ is the velocity of the sth particle at the dth dimension in the τth iteration;

PBest_{sd} and GBest_{sd} are the personal best position (pbest) and the global best position (gbest) of the sth particle at the dth dimension in the τth iteration, respectively;

$\mathrm{LBest}_{sd}(\tau)$ and $\mathrm{NBest}_{sd}(\tau)$ are the local and near neighbor best position of the sth particle at the dth dimension in the τth iteration, respectively;

$P_{sd}(\tau)$ is the position of the sth particle at the dth dimension in the τth iteration;

c_p and c_g are positive constants (i.e., learning factors) which determine the relative weight and reflect the comparison between the global best and the personal best;

c_s and c_n are the global and near neighbor best position acceleration constants, respectively;

r_p, r_g, r_l and r_n are uniform random numbers in the interval [0, 1].

And $\omega(\tau)$ is the inertia weight used to control the influence of the previous velocities on the current velocity, which is set as follows:

$$\omega(\tau) = \omega(N) + \frac{\tau - N}{1 - N}[\omega(1) - \omega(N)]. \quad (85.15)$$

When updating the particle position, the new velocity is:

$$P_{sd}(\tau+1) = P_{sd}(\tau) + \upsilon_{sd}(\tau+1). \quad (85.16)$$

The near neighbor best (nbest) proposed by Veeramachaneni [15] is a social learning behavior concept and is determined using a fitness-distance-ratio (FDR).

$$\mathrm{FDR} = \frac{\mathrm{Fitness}(P_s) - \mathrm{Fitness}(P_o)}{|P_{sd} - P_{od}|}, \quad (85.17)$$

where P_s and P_o are the vector positions of the sth particle and oth ($o = 1, \ldots, S$ and $o \neq s$) particle.

The pbest, gbest, lbest and nbest are updated in accordance with the following rules: For $s = 1, 2, \ldots, S$, Update pbest: If Fitness $(P_s) <$ Fitness(PBest_s), $\mathrm{PBest}_s = P_s$.

Update gbest: If Fitness $(P_s) <$ Fitness(GBest), GBest $= P_s$.

Update lbest: If one personal best has the least fitness value of all the pbest from K neighbors of the sth particle, then it is set as the LBest_s which is the vector's local best position for the sth particle.

Update nbest: For $d = 1, \ldots, D$ (D is the size of the dimension), the P_{od} is set, which maximizes the value of the FDR to be the NBest_{sd}.

85.3.5 *Overall GLNPSO-LPT*

We illustrate the GLNPSO-LPT procedure as follows [10].

Step 1 Set the parameters: the number of particles S, maximum position value $P^{\max}$, minimum position value $P^{\min}$, inertia weight ω, four acceleration constants c_p, c_g, c_l, c_n, and four uniform random numbers r_p, r_g, r_l, r_n.

Step 2 Generate the two swarms, A and B.

Step 3 For all particles, do:

- **Step 3.1** For $s = 1, \ldots, S$, decode each particle to a job sequence. Calculate the fitness value of each particle and set the position of the sth particle as its personal best. Choose the best of these personal best positions as the global best position.
- **Step 3.2** Update pbest, gbest, lbest and nbest.
- **Step 3.3** Update the particle positions and velocities.
- **Step 3.4** Judge, if the position is in the feasible region:

$$\text{If } P_{sd}(\tau + 1) > P^{\max}, \text{ then } P_{sd}(\tau + 1) = P^{\max}, \omega_{sd}(\tau + 1) = 0,$$
$$\text{If } P_{sd}(\tau + 1) < P^{\min}, \text{ then } P_{sd}(\tau + 1) = P^{\min}, \omega_{sd}(\tau + 1) = 0.$$

Step 4 Every 20 iterations, exchange particles between the two swarms.

Step 5 If the stopping criterion is met, stop; otherwise, $\tau = \tau + 1$ and return to Step 3.

85.4 Computational Experiment

To gain insight into the performance of the proposed method, several computational experiments were conducted. As an illustration of the heuristic, consider parallel machines scheduling problem with 30 jobs, 3 machines and 3 maintenance activities taken from one plant in a textile company, the details of for which are given in Table 85.1. To determine the performance of the proposed GLNPSO-LPT algorithm,

Table 85.1 The original data for maintenance activities (in hours)

Time windows	PM_{11}	PM_{12}	PM_{13}
$\tilde{PME}^e_1, p_1$	[(12.0, 12.4, 12.6), 0.3]	[(15.0, 15.4, 15.6), 0.5]	[(13.0, 13.3, 13.7), 0.6]
$\tilde{PML}^e_1, q_1$	[(13.1, 13.3, 13.9), 0.3]	[(16.1, 16.3, 16.4), 0.4]	[(14.9, 15.0, 15.1), 0.4]
$\tilde{PME}^e_2, p_2$	[(11.7, 12.2, 12.8), 0.7]	[(14.8, 14.9, 15.2), 0.3]	[(12.8, 12.9, 13.0), 0.6]
$\tilde{PML}^e_2, q_2$	[(13.2, 12.4, 12.6), 0.7]	[(16.0, 16.4, 16.6), 0.3]	[(15.0, 15.1, 15.2), 0.4]
$\tilde{PME}^e_3, p_3$	–	[(15.2, 15.3, 15.4), 0.2]	–
$\tilde{PML}^e_3, q_3$	–	[(16.3, 16.6, 16.8), 0.3]	–
PME	12.3	15.4	13.2
PML	13.1	16.3	15.0
a_{kj}	1	0.8	1.7

some computational experiments were conducted on model (85.12) using MATLAB 7.0 on a Pentium 4, 2.40 GHz clock pulse with 2048 MB memory.

In the experiments, it was found that the GLNPSO-LPT generally converged within 200 iterations, so to ensure the convergence of the algorithm, the iteration number was set at $N = 300$ for this solution algorithm. To determine the best suitable values for c_p, c_g, c_l, c_n, the population sizes for swarm A and swarm B and the initial and final inertia weights $\omega(1)$ and $\omega(N)$, results were obtained using different GLNPSO-LPT parameters. Experiments for 20 parameter group candidates were conducted, the most suitable parameters selection was that: $c_p = 1.5$, $c_g = 2$, $c_n = 1.8$, $c_l = 2$, where the population sizes for swarm A and swarm B were both set at 30, the initial inertia weight $\omega(1) = 0.8$, and the final inertia weight $\omega(N) = 0.2$.

Table 85.2 shows the results obtained using the GLNPSO-LPT, PSO and GA algorithms in the fuzzy random and fuzzy and random environments. It was found that no matter the situation, the GLNPSO-LPT algorithm can provided the best solution. Although the GLNPSO-LPT had a slightly longer computation time than the PSO,

Table 85.2 Comparison results between the GLNPSO-ff, PSO and GA

Environment types	GLNPSO-LPT		PSO		GA	
	f_1^*, f_2^*	Average CPU time	f_1^*, f_2^*	Average CPU time	f_1^*, f_2^*	Average CPU time
Fuzzy random	(30.35, 0.8470)	7.15	(33.15, 0.8045)	6.55	(37.44, 0.7895)	10.34
Random only	(34.22, 0.8322)	8.78	(36.47, 0.8142)	7.34	(39.87, 0.7512)	12.65
Fuzzy only	(33.89, 0.8089)	8.56	(35.66, 0.7970)	8.15	(39.55, 0.7412)	11.86

it was still considered more suitable because the decision maker would prefer a better solutions if the computation times were similar. From these experiments, it was clear that the model that considered both fuzzy factors and random factors had a significantly better performance than the other models, as the fuzzy data allowed for a relaxing of the requirements on the time windows. In sum, the GLNPSO-LPT algorithm was able to find a better solution and also had a better performance than either the PSO or GA in the proposed problem.

85.5 Conclusion

In this paper, a scheduling problem on parallel machines subject to fuzzy random time windows was studied. The main purpose was to meet demands of both production scheduling and maintenance planning. Then, there were two objectives considered, minimizing the makespan and maximizing average timeliness level. First, a fuzzy random variable for maintenance time windows was considered, and this model was then transformed using the expected value. Then, an instance of the algorithm was demonstrated to illustrate the applicability of the proposed approach and the results obtained were highly favourable.

References

1. Ebrahimipour V, Najjarbashi A, Sheikhalishahi M (2015) Multi-objective modeling for preventive maintenance scheduling in a multiple production line. J Intell Manuf 26(1):111–122
2. Garey MR, Johnson D (1981) Approximation algorithms for bin packing problems: a survey. Anal Des Algorithms Comb Optim 266:147–172
3. Gil MÁ, López-Díaza M, Ralescu DA (2006) Overview on the development of fuzzy random variables. Fuzzy Sets Syst 157:2546–2557
4. Jiang D, Tan J (2016) Scheduling with job rejection and nonsimultaneous machine available time on unrelated parallel machines. Theoret Comput Sci 616(22):94–99
5. Kennedy J, Eberhart R (1995) Particle swarm optimization. In: Proceedings of the IEEE conference on neural networks, Piscataway, NJ, USA
6. Kruse R, Meyer KD (1977) Statistics with vague data. Springer, Berlin
7. Lee CY (1996) Machine scheduling with an availability constraint. J Global Optim 9(3):395–416
8. Li K, Zhang X et al (2016) Parallel machine scheduling problems in green manufacturing industry. J Manuf Syst 38:98–106
9. Ma Y, Xu J (2014) A cloud theory-based particle swarm optimization for multiple decision maker vehicle routing problems with fuzzy random time windows. Eng Optim 47(6):825–842
10. Nie L, Xu J, Tu Y (2014) Maintenance scheduling problem with fuzzy random time windows on a single machine. Arab J Sci Eng 140(3):959–974
11. Peng J, Liu B (2004) Parallel machine scheduling models with fuzzy processing times. Inf Sci 166:49–66
12. Pinedo M (2012) Scheduling: theory, algorithms and systems. Springer, New York
13. Santos FC, Brojo F, Vilarinho PM (2012) Lot sizing and scheduling in parallel uniform machines–a case study. Research Gate

14. Skutella M (2013) Algorithms and linear programming relaxations for scheduling unrelated parallel machines. In: Experimental algorithms. Springer, Berlin, pp 1–3
15. Veeramachaneni K, Peram T, Mohan C, et al (2003) Optimization using particle swarms with near neighbor interactions. In: Genetic and evolutionary computation-gecco. Springer, Berlin, pp 110–121
16. Wang LY, Huang X et al (2014) Unrelated parallel-machine scheduling with deteriorating maintenance activities to minimize the total completion time. Optimization Letters 8(1):129–134
17. Xu J, Feng C (2015) Two-stage based dynamic earth-rock transportation assignment problem under fuzzy random environment to earth-rock dam construction. J Civil Eng Manage 21(6):775–797
18. Yang SJ (2013) Unrelated parallel-machine scheduling with deterioration effects and deteriorating multi-maintenance activities for minimizing the total completion time. Appl Math Model 37(5):2995–3005
19. Zinder Y, Walker S (2015) Algorithms for scheduling with integer preemptions on parallel machines to minimize the maximum lateness. Discrete Appl Math 196:28–53

Chapter 86
Intensified Water Treatment Methods

Gheorghe Duca and Olga Covaliova

Abstract A review paper, describing the history of water pollution, appearance and development of water treatment technologies and systems. Intensive economic activity has become especially hazardous for the state of our environment. Today we are witnessing the progressive pollution of water environment. In some cases it is impossible to reach the satisfactory water treatment quality using the single/double step treatment or only the conventional methods. The treatment of waste waters using the combined methods and applying the intensified conditions, as well as elaboration of the continuous-action integrated reactors is a prospective research trend throughout the world and a number of research institutions and teams are involved in the studies in this important area. An overview of intensified and combined wastewater treatment methods, processes and reactors elaborated by researchers from Moldova, is given, including electrochemical, photo-catalytic and biochemical ones.

Keywords Wastewater · Hazardous pollutants · Treatment methods · Intensified conditions · Integrated reactors · Electrochemical processes · Photocatalytical treatment · Biochemical methods

86.1 Introduction

86.1.1 Water Resources and Pollution Problem

All the living organisms on our Planet, including humans, are consistent of water by 2/3. Fresh water reserves make no more than 3 % of all the water amount on the Earth, making 1350 bln km^3, out of them only 0.06 % or 0.8 bln km^3 are fresh water resources available for the mankind.

In the last years the problem of good quality potable water supply for the population has become very acute. The mostly spread admixtures in the ground waters

G. Duca · O. Covaliova (✉)
Academy of Sciences of Moldova, Chisinau, Republic of Moldova
e-mail: ggduca@gmail.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_86

are the compounds of bivalent iron and manganese, fluorine ions, nitrates, ammonia, hydrogen sulphide, high salinity, which is mostly stipulated by the geological factors. At the same time, the good quality water useful for humans' health should contain the broad spectrum of biologically active elements and micro-admixtures of natural organic compounds. For a long time the water from shallow wells and water springs was considered to be pure and safe for drinking scopes, whereas the water treated with chlorine, or the distilled water was considered as a "dead" water. The other water supply source are surface fresh waters.

The pollution of natural waters occurs as long as our Planet exists. However, there are specific water self-purification mechanisms in the nature. With the appearance of Homo sapiens, the scale of water pollution has increased tremendously, first, as a result of humans vital activity and metabolism, and then because of development and application of technological processes: the man started to process the raw materials, the planet's resources, polluting the soil, air and water. The global economic activity, especially in the $XIX - XXI$ centuries, connected with the development of industry, transport, growth of cities and settlements, has provoked the large-scale anthropogenic pollution of natural underground and surface waters with industrial, agricultural of municipal wastewaters.

Due to the increased pollutions load and a great number of new substances and materials discharged in water bodies, the natural water purification processes were unable to provide the efficient return of water condition to its initial state, specific for the Earth. The wastewaters composition becomes more and more complex, due to the synthesis of new chemicals and compositions, which often possess the toxic properties. The most dangerous of them are considered to be the inorganic compounds, first of all the heavy metal salts, and a great variety of organic compounds, including the oil products, polyphenols, pesticides, surfactants, chlorine organic compounds, xenobiotics, pollutants with mutagenic properties, bacterial, micosic and virus pollutants, hormonal medicinal preparations. It is to be especially stressed that nowadays for the majority of new pollutants, incoming the environment, there is no exact and reliable information with regard to their composition, toxic properties towards the living organisms, environmental behavior and fate. Meanwhile, an objective to provide water treatment and its reuse (for irrigation, watering the field crops, technical operations at the industries and some household applications) is undoubted priority.

86.1.2 Water Treatment Issues

To reduce the pollutants load on the natural environment, to assist the nature coping with the pollution-caused challenges, and at the same time to provide the appropriate living conditions for themselves, people started to apply water treatment and purification systems, methods and devices. Some of these processes are known since the ancient times, and still they are used in our practice. Among the well-known and broadly applied conventional methods are: simple dilution, mechanical treatments (including filtration on sand and combined filters), chemical treatment (when

Fig. 86.1 The simple biogas reactor in Ancient China: treatment of agricultural wastes and wastewaters with organics load

chemicals are used to treat acid, alkaline or other waters with specific composition), biochemical processes (including anaerobic and/or aerobic treatments) (Fig. 86.1), physical effects (UV-irradiation, oxidation, etc.).

At current stage of technology development, to provide more efficient and economically justified treatment of heavily polluted wastewaters, a combination of different approaches should have been proposed (two, three and even more methods applied consecutively or simultaneously), specifically: biochemical and photochemical treatments, electrochemical and physical processes, physico-chemical and biological methods, etc. To test and ensure practical application of these methods, a series of integrated reactors have been developed. Apart from a combination of methods, there are other approaches proposed to intensify the occurring physical, chemical and biochemical processes resulting in the removal or degradation of the pollutants in treated waters.

86.2 Modern Intensified Water Treatment Technologies

86.2.1 Electrochemical Treatment of Industrial Waste Water Containing Heavy Metals

Ferritization technology. The industrial wastewaters and liquid waste solutions resulted from the chemical and electrochemical processing of metals' and alloys' surface are among the most dangerous pollution sources for natural waters and soil. They, as a rule, contain such metals (*d*-elements) as Cu, Cd, Zn, Cr, Ni, etc. [2].

Application of electrochemical "ferritization" water treatment methods of multicomponent wastewaters makes it possible to resolve a series of important technological, ecological and social-economical problems [11]. These issues imply the possibility to remove the heavy metal ions from industrial wastewaters, that are present in the form of water-soluble complexes within the broad pH range, such as ammonia complexes. The other problem solved due to this treatment technology, is the formation of wastewater sludge that can be readily separated in the gravitational and magnetic field. This becomes possible due to the high hydraulic size of particles, the crystal structure of formed sediments and their ferro-magnetic properties. The third important problem that can be solved with ferritization treatment methods, is the possibility to obtain the sediments in the form of oxide structures with low leachability of components during the storage and utilization, as compared to the heavy metal hydroxides [12]. On one hand, due to such properties of formed sediments, the treatment degree of wastewaters is improve significantly, on the other hand-an important ecological problem is solved: the soil and water pollution during the sediments storage is prevented.

Apart from these advantages, the ferritization water treatment technology makes it possible to utilize the sediments possessing the oxide-spinel structure. It is to be noted that the metal hydroxide compounds, extracted from the wastewaters in accordance to the conventional technologies, in spite of the great efforts of researchers, have not found the real utilization ways.

Electrochemical ferritization method of wastewater treatment, containing the heavy metal ions, is based on the iron electrodes dissolving under the application of constant, reverse or periodic current with the regulated reverse moment [5]. As a result, a series of electrochemical processes occurs on electrodes, whereas in the bulk of solution the reduction-oxidation reactions are running. They are accompanied with the formation of hydroxide sediments which undergo phase-disperse transformations, resulting in the formation of oxide structures. Application of electrochemical coagulation method (as a separate step or in combination with electro-flotation or other methods) allows to reach the efficient and deep purification of waste waters.

The efficiency of electrochemical process is determined by the rate of electrode reaction, and the ratio between the zone of electrochemical reaction with regard to the total bulk of reactor.

There are two main pollutants removal mechanisms during the electrochemical treatment:

(1) Redox-processes, resulting in the admixtures transformation into the water insoluble form/solid phase, for example, during the reactions:

$$Cr_2O_7{}^{-2} + 6Fe^{+2} + 14H^+ \rightarrow 6Fe^{+3} + 2Cr^{+3} + 7H_2O,$$
$$Fe^{+3} + 3OH^- \rightarrow Fe(OH)_3 \downarrow,$$
$$Cr^{+3} + 3OH^- \rightarrow Cr(OH)_3 \downarrow .$$

(2) Adsorbtion mechanism, when the admixture removal occurs due to the adsorbtion on the hydroxides.

A combination of both mechanisms in a single process is also possible.

The rate constant of pollutants removal is given, considering the electrochemical and adsorbtion methanisms:

$$\kappa = \Gamma_{\infty i}\eta \frac{IA}{VnF},$$

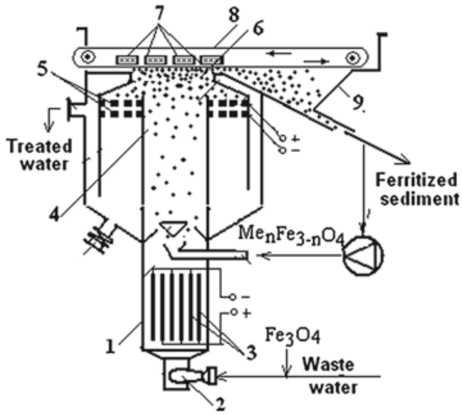


Fig. 86.2 A scheme of integrated reactor for ferritization treatment of multi-component waste waters: 1—case; 2—waste water inlet; 3—soluble iron electrodes; 4—flotation chamber; 5—insoluble electrodes (cathodes); 6—floto-concentrate of ferrite sediment; 7—magnets; 8—transporter; 9—bunker [9]

where V is volume of solution, A is atomic weight of dissolved metal, I is current, nF is charge, transferred during the dissolving reaction (F is Faraday's constant), η is metal yield. Therefore, the intensifying factors in such water treatment processes are the increase in the anodic dissolving rate (ηI) and admixtures adsorptivity (Γ_∞).

The low-temperature ferritization process occurs with the introduction in the electrochemical reactor of magnetite particles (Fe_3O_4), which exert the catalytic action. In this way, the conditions for the treatment of multi-component wastewaters are ensured. The process can be performed in the integrated reactor (Fig. 86.2).

Experimental studies (Table 86.1) have shown that the efficiency of ferritization processes is above the efficiency of conventional electrocoagulation method, due to the higher chemical stability of formed sediments [13].

As follows from the results obtained, the ferritization process ensures the reducing of metal contents in treated water up to the discharge requirements into the sewer-

Table 86.1 Comparative characteristics of electrochemical treatment methods

No.	Initial contents in metal ions in the ammonia-containing waste waters		Resulting metal concentration after the treatment (mg/l)		
	Metal	Metal concentration (mg/l)	Electrocoagulation process	Ferritization process	
				20°	70°
1	Cu^{2+}	17	2.9	Not detected	Not detected
2	Ni^{2+}	14	2.3	0.1	0.05
3	Zn^{2+}	26	3.5	0.2	0.1
4	Cr(VI)	21	4.1	0.2	0.05

Process parameters: pH = 7.3; electrode material-steel 3; inter-electrode gap = 5 mm ; $I_k = I = 1,5$ /dm^2; treatment time = 150 s age system and surface waters [6]. The electrolysis under the elevated temperatures provides the better treatment results, compared to the process under the room temperature, although the both technologies ensure reaching the treatment standards.

Galvano-chemical treatment of waste waters. Galvano-chemical treatment processes are based on the dissolving of iron in the field of closed circuit galvanic element Fe-coke, due to the contact of galvanic pair elements between themselves. These processes are advantageous due to their energy-saving specifics, when there is no need to apply the external current. The coke is polarized cathodically, whereas the iron is dissolved, acting as anode. In the presence of oxygen the following reactions occur on cathode:

$$2H_2O + O_2 + 4e = 4OH - \aleph Me^{\Pi +} + ne = Me.$$

During the anodic dissolving of iron a series or reactions are running:

$$\begin{aligned} Fe + 2OH^- &= Fe(OH)_2 + 2e, \\ 4Fe(OH)_2 + O_2 &= 4FeOOH + 2H_2O, \\ Fe + 2H_2O &= Fe(OH)_2 + 2H^+ + 2e, \\ Fe + 3H_2O &= Fe(OH)_3 + 3H^+ + 3e. \end{aligned}$$

A modified galvano-chemical treatment method of metal-containing wastewaters and a reactor have been proposed (Fig. 86.3). The process was carried out at room temperature with introduction of magnetite particles, initiating the development of auto-catalytic process [309, 420–423].

The technological tests have demonstrated that the wastewaters with the initial contents, mg/l: Cr(V1)—24.8; Ni(II)—16.5; Cu(II)—12.3; Zn(II)—17.4, pH = 6–8, being treated under the proposed conditions, have been purified up to the ruling treatment parameters [6]. As a result, a sludge with ferro-magnetic properties was

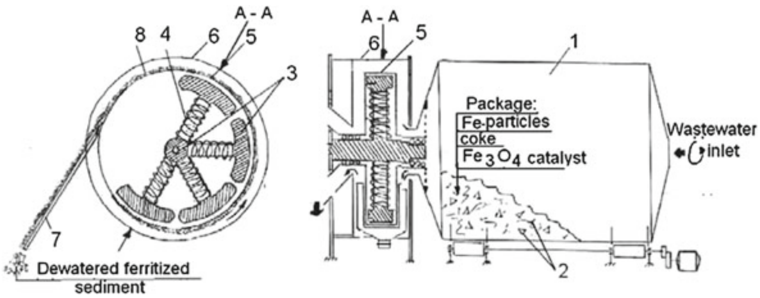


Fig. 86.3 The scheme of galvano-chemical reactor: *A*—general view; —lateral section by line ≪ $A - A$ ≫: 1—case; 2—package ≪ Fe/coke/magnetite ≫; 3—magnets; 4—winding; 5—rotating non-magnetic case; 6—protective case; 7—scraper; 8—ferrite sediment [8]

obtained, which ensured its easy separation from the treated water in the magnetic field.

Using of flow-through 3d-electrodes for electrochemical treatment of low-concentrated waste waters.Electrochemical treatment methods are more ecologically pure processes, compared to the conventional reagent treatment, as in allows to extract the metals in pure form and reduce the amounts of wastes. However, to treat the waste solutions with low concentration of electroactive components, the possibility to apply electrochemical technologies is limited by the low process efficiency on the plate electrodes, first of all, due to the low electric conductivity of treated solutions. The very low metal current yield is observed already at the metal concentrations of about 10 mg/l.

Application of flow-through 3d-electrodes from the carbonic materials allows to overcome these disadvantages and to enhance the efficiency of electrochemical treatment and metal extraction degree, due to the intensification of mass-exchange, increase in specific reaction surface and metal yield [7]. It was shown that the metal extraction level up to remaining contents in 1.0 mg/l and less can be reached, using this technology.

A compact pilot electroreactor has been developed (Fig. 86.4), including two anode chambers, separated from the cathode one with the ion-exchange membranes. The 3d-electrodes were made of a foamy metals 1–1.2 cm depth. The tests have shown the reducing of Cr(VI) to Cr(III) up to its residual concentrations of 0.24–0.34 g/l.

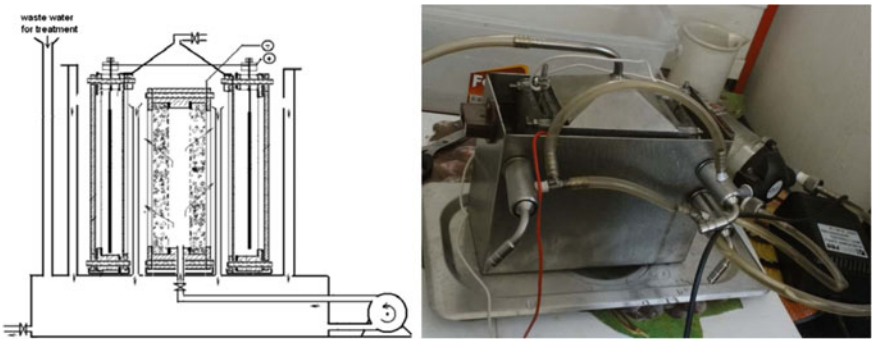


Fig. 86.4 Scheme and general view of a pilot electroreactor for treatment of low-concentrated wastewaters, using the flow-though 3d-electrodes [10]

86.2.2 Photocatalytical Treatment of Waste Waters Containing the Persistent Organic Pollutants

Photocatalytical processes of organic pollutants destruction in water compartments can be subdivided in three main types: homogeneous, heterogeneous and mixed ones. These technologies can be applied in common with other physical-chemical and biochemical methods. In case of the soluble pollutants, the homogeneous processes are more advantageous, as they allow the penetration of UV-irradiation into the bulk of treated solution.

The UV-irradiation initiate the formation of peroxide compounds and a series of free radicals [4]. Among the various metals, the soluble iron-containing compounds are readily available and the efficient photo-inductors. The photo-catalytic effect discovered by Fenton in the end of *XIX*th century in the system $\ll Fe^{3+}/H_2O_2/$ UV-irradiation $\gg$ has promoted the appearance of a new research direction, which is today developing within the frames of the ecological chemistry. This direction allows to explain the processes of organic substances transformations in the natural water compartments, which were used for the elaboration of new methods and reactors of polluted wastewaters treatment and preventing of their discharges into the environment.

The organic toxicants can be subdivided into the easily biologically degradable ones and the persistent pollutants. The compounds that practically cannot be mineralized/decomposed by the conventional methods are of specific danger, among them C-benzothiasols (BTs), which molecules have the benzene ring conjugated with the thiol ring and functional groups. A large-tonnage commercial production of these substances and various applications provoke their discharges in the natural environment and waste waters.

The general destruction scheme of BT destruction in the presence of photo-inductor and microorganisms, according to [1], is presented on Fig. 86.5.

To perform the photo-catalytical and biochemical processes of wastewater treatment containing the persistent organics, a special integrated photo-reactor has been developed and tested (Fig. 86.6). The equipment involves the case with UV-lamps (1). The inner quartz walls of reactor are cleaned with the system of brushes (2), connected with eccentric mechanism (4) and electric engine (3). There is a possibility to additionally introduce air in the reactor (5) to intensify the photo-redox processes.

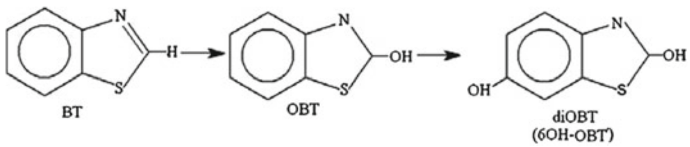


Fig. 86.5 The general destruction scheme of BT destruction in the presence of photo-inductor and microorganisms

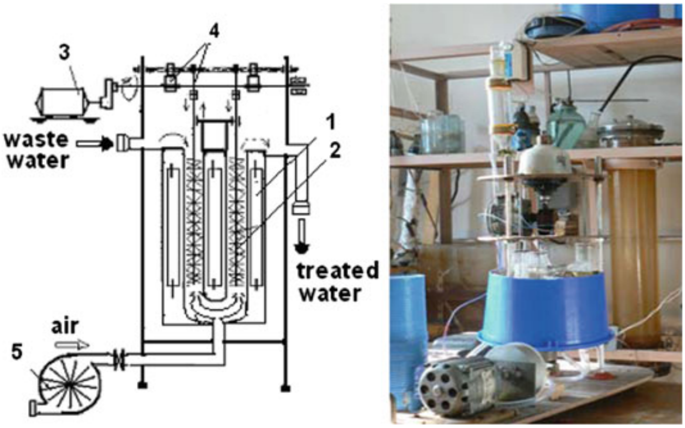


Fig. 86.6 The scheme and general view of dynamic action reactor for photo-catalytic destruction of persistent organic pollutants

The low pressure lamp with 253.7 nm wavelength was used. It was found that using the H_2O_2 and $K_3[Fe(C_2O_4)_3]$ as photoinductor under the pH = 7.0, it became possible to reach 70-80 % desctruction degree of pollutant within 180 min of treatment. The process running was controlled by HPLC method. The analysis of chtomatograms has shown that with the disappearance of peaks corresponding to BT, a series of new peaks appeared, corresponding to OBT and other intermediate products. The further experiments have demonstrated that the consecutive application of photochemical and biochemical treatment of BT-containing wastewaters makes it possible to reach the complete mineralization of organics, with the formation of inoffensive final products, such as water and inorganic salts.

A series of other hybrid reactors has been elaborated, which may be used for the destruction of persistent organics in water solutions.

86.2.3 Biochemical Treatment of Agro-Industrial Waste Waters

The biochemical treatment of municipal and agro-industrial wastewaters with high organic loads has been known and broadly applied throughout the world for the decades already. The mechanism of biochemical fermentation of organics in the wastewater can be given with the following reactions:

$$4H_2A + CO_2 \rightarrow 4A + CH_4 + 2H_2O,$$
$$2H_2 + CO_2 = CH_4 + 2H_2O,$$
$$2C_2H_5OH + CO_2 = CH_4 + 2CH_3COOH,$$

$$3C_4H_9OH + CO_2 = CH_4 + 2C_3H_7COOH,$$
$$4CH_3CHOHCH_3 + CO_2 = CH_4 + 4CH_2COCH_3 + 3H_2,$$

where H_2A is any organic hydrolyzed ingredient.

However, it was shown that these well-known and studied processes still can be significantly modified and improved, to make a conventional technology more profitable and intensive.

Thus, a new-generation intensive ecological technology and integrated bioreactor for biogas production through the valorisation of agro-industrial wastes which are hazardous being dumped in the natural environment has been developed [3]. This technology is innovative and is based on the use of natural phyto-catalysts introduced in the digested biomass in micro-concentrations of 10^{-3}–10^{-5}%. These additives are obtained by extraction from natural vegetable feedstock and wastes. Phytocatalysts promote 1.5–2 times acceleration of methanogenic process and increase in biomethane contents in biogas up to natural gas level. Biomethane contents in biogas is thus increased from 62 % with caloric value of 5232 kcal/m^3, to 89–93 % with caloric value of 8010 kcal/m^3. In addition, the stabilized biomass residues (digestate solids) obtained can be used as organic fertilizers, whereas the treated water meets the requirements for irrigation scopes. The technology proposed ensures the generation of a renewable "green" heat and electric energy, and contributes to the improvement of energy and environmental security in accordance with the existing national and international standards. It is beneficial from efficiency and costs point of view and will enhance the know-how of participating industries especially increasing their competitiveness.

86.3 Conclusions

The overview of natural water pollution and water treatment technologies has demonstrated that at present stage of humans civilization development, with the appearance and discharges of huge amounts of new chemicals in natural water environment, the convenient treatment methods are insufficient and inefficient to reach the treatment requirements.

Therefore, new approaches have been developed with regard to wastewater treatment technologies, and a conclusion was made that the intensive and combined technologies can allow to treat the industrial, agricultural and municipal wastewaters with higher efficiency and in an ecologically-friendly manner.

Thus, a newly developed ferritization, galvanochemical and electrochemical treatment technology using the flow-through 3d-electrodes makes it possible not only to meet the water treatment standards, but also to obtain the resulted products in the form of stable chemicals-either the pure metals or insoluble oxide forms. These sediments can be easily separated from treated water and utilized in technological and other processes.

The modified photo-catalytical processes in combination with the biochemical treatment are good solutions to treat the wastewaters containing the persistent organics. Mineralization of stable xenobiotics can be reached, due to the reactors and treatment technology proposed.

A novel way of biochemical treatment of agro-industrial wastewaters have been proposed in order to intensify the well-known biogas processes and systems. The proposed approach implies introduction of special micro-additives of natural origin in fermented mixture, thus making it possible to shift the reaction route in the desired area and significantly intensify the water treatment process.

The application of modern intensified technologies is justified when it is necessary to ensure the advanced and intensive treatment of specific wastewaters.

References

1. Andreozzi R, D'Apuzzo A, Marotta R (2000) A kinetic model for the degradation of benzothiazole by Fe^{3+} photo-assisted fenton process in a completely mixed batch reactor. J Hazard Mater 80(1):241–257
2. Chen G, Hung YT (2007) Electrochemical wastewater treatment processes. In: Proceedings of the advanced physicochemical treatment technologies, Springer, Berlin, pp 57–106
3. Covaliov V, Bobeica V et al (2015) New technology and modified bioreactor implementation for winery wastewater treatment: a case study in Moldova, p 8
4. Duca G (2012) Homogeneous catalysis with metal complexes: fundamentals and applications, vol 102. Springer, Berlin
5. El-Gayar D, El-Shazly A et al (2010) Effect of electrode pulsation on the rate of simultaneous electrochemical recovery of copper and regeneration of ferric salts from dilute solutions. Chem Eng J 162(3):877–882
6. European Committee for Surface Treatment (2001) Reference document on best available techniques. p 69
7. Kiyohara K, Sugino T, Asaka K (2010) Electrolytes in porous electrodes: effects of the pore size and the dielectric constant of the medium. J Chem Phys 132(14):144705
8. Patent MD (2004) Reactor for galvanochemical obtaining of fine ferrite sediments. BOPI
9. Patent MD (2008) Apparatus for electrochemical treatment of metal-containing waste waters. BOPI
10. Patent MD (2008) Electrolyser for hydrogen production. BOPI
11. Rizo EG, Lubman IA, Dmitriev SN (2006) Universal technology of heavy metal deposition from waste waters-ferritization technology. Water Ecol Prob Solut 3:32–37
12. Semenov VV, Varlamova SI, Klimov ES (2005) Plating sludge utilization with ferritization method. Proc Univ Chem Chem Technol 48:111–112
13. Yang J, Peng J et al (2007) Synthesis of ferrites obtained from heavy metal solutions using wet method. J Hazard Mater 143(1):379–385

Chapter 87
Constructing Forecasting Model of No-Failure Operation of Pump Stations

Yasin Rustamov and Gorkhmaz Afandiyev

Abstract In the paper a construction of a forecasting model by using the Bayes formula is considered. The constructed model allows to estimate real state of pump stations in due time and to take urgent measures on problem solving and therewith to provide no-failure operation of the system during the demanded interval of time.

Keywords Bayes formula · Pump station · Forecasting · Probability of stoppage · Probability of no-failure operation · Reliability

87.1 Introduction

In the areas of arid climatic zones pumping stations are widely used, because irrigation is realized by artificial method. Pump stations are designed for water transportation from reservoirs to certain distances, and also for water transfer from main and irrigation channels to certain height. At the same time, pump stations are used to evacuate mineralized ground waters from fields in mild slope regions. Provision of continuous operation of hydromeliorative systems, extension of their lifetime, stability improvement and lowering of operational costs is one of the urgent problems standing before science. One of the methods for solving these problems is estimation of reliability of the existing systems and constructions and to take into account the results in elaboration phase of reliability project. From this point of view, forecasting of pump stations stoppage in order to increase reliability and provide no-failure operation of the system is an urgent problem.

Y. Rustamov (✉) · G. Afandiyev
Institute of Control Systems, Azerbaijan National Academy of Sciences,
Baku, Azerbaijan
e-mail: yasin.rustamov@gmail.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_87

87.2 Problem Statement

We have provided with information on stoppages of pump stations in the course of a year. The problem is to construct forecasting model of probability of no-failure operation of the system in the course of the demanded interval of time, using these data.

87.3 Solution

We use the Bayes known formula that is successfully used for forecasting different phenomena [1–4].

$$P(A_k/x_j^i) = \frac{P(A_k)P(x_j^i/A_k)}{\sum\limits_k P(A_k)P(x_j^i/A_k)}, \tag{87.1}$$

where $P(A_k)$ is a priori probability of the state A_k, $k = 1, 2, \ldots, l$; $\sum\limits_k P(A_k) = 1$;

$P(x_j^i)$ is a priori probability of gradation x_j^i, $j = 1, 2, \ldots, r$; $i = 1, 2, \ldots, m$;
r is the total number of indicators, m is the number of values of each indicator.

In our case there are 2 variants of state: A_1, the pump station operates, A_2, the pump station doesn't operate.

The data of 86 pump stations were considered, 48 of them in operating condition (in planned inspection), 38 under failure (i.e. don't operate).

As a result of analysis, the data on stoppages (or failures) were grouped by essential indications. By empirical data the following essential factors influencing on no-failure operation of the pump station: state of the pump unit, disturbance of lift height, productivity decrease of the pump system, were determined. Such an approach admits to determine constructive causes and the causes related to mismanagement of an exploiter. By the above data, a priori probabilities of the states: $P(A_1) = 0, 56$; $P(A_2) = 0, 44$ were calculated.

In non-operational pump stations the above factors had the following frequencies:

(1) The state of the pump unit: $P(x1/A2) = 27/38 = 0.71$;
(2) Disturbance of the lift height: $P(x2/A2) = 5/38 = 0.13$;
(3) Productivity decrease of the pump system: $P(x3/A2) = 6/38 = 0.16$.

Further, gradations of every factor were studied separately.

(1) State of the pump unit

Existence of abrasive particles in water reservoirs, nonperformance of planned overhaul in specified period and other factors connected with operation (failures in electric system, disturbance of safety laws, etc.) reduce to wear of internal parts. As a result of this, the coefficient of effective operation of the pump gradually decreases and the pump station discontinues its operation. To a certain extent, these phenomena are expected, but they may be forecasted and predicted.

The results of investigation of the pump unit are given in Table 87.1.

Taking into account frequency data, the diagnostic table was composed (Table 87.2).

Certainty ratio equal to ratio of frequencies of indicators in operating and non-operating systems was calculated by the formula

$$O\prod = \frac{P(x_j^i/A_1)}{P(x_j^i/A_2)}. \tag{87.2}$$

Diagnostic coefficient (DC) is the logarithm of certainty ratio multiplied by

$$DC = 10\lg\frac{P(x_j^i/A_1)}{P(x_j^i/A_2)} \tag{87.3}$$

Table 87.1 The main malfunctions of a pump unit

Main causes of malfunctions (x_j^i)	In operating condition ($n = 48$)		In non-operational condition ($n = 27$)		Certainty of difference
	abc.	%	abc.	%	
Existence of abrasive particles	8	16.67	22	81.48	$p < 0.001$
Nonperformance of planned overhaul	23	47.92	2	7.41	$p < 0.05$
Other factor related to operation	17	35.42	3	11.11	$p < 0.001$
Total	48	100	27	100	

Table 87.2 Diagnostic table of malfunction of the pump unit

Main causes (x_1^i)	Number of observations		Probability		Certainty	DC
	Oper.	Non-oper.	$P(x_1^i/A_1)$	$P(x_1^i/A_2)$		
Existence of abrasive particles	8	22	0.167	0.815	0.20	−6,89
Nonperformance of planned serviceability	23	2	0.479	0.074	6.47	8.11
Other factors related to operation	17	3	0.354	0.111	3.19	5.03
Total	48	27	1	1		

(2) Disturbance of lift height

Lowering of the water level in antechamber may reduce to velocity increase of water, fall of pressure in operating chamber of a pump and increase of lift height. As a result, there appear cavitation phenomena, and this in its turn may reduce to change of engineering factors and malfunction of the pump station.

The results of investigations are given in Table 87.3.

Taking into account these data, the diagnostic table was composed (Table 87.4).

Certainty ratio and diagnostic coefficient are calculated by formulas (87.2) and (87.3).

(3) Productivity decrease of the pump unit

Usually, productivity decrease of a pump system occurs under wear of internal parts, decrease of leak tightness of a pump and other factors. Delay of performance of prophylactic works may reduce to unexpected stoppages of a pump station.

The results of investigations are given in Table 87.5.

Taking into account the data, the diagnostic table was composed (Table 87.6)

Table 87.3 Disturbance of specified lift height

Disturbance of height (x_2^i)	In oper. condition ($n = 48$)		In non-oper.condition ($n = 5$)		Certainty of of difference
	abc.	%	abc.	%	
0–10 %	36	75.0	1	20.0	$p < 0.001$
10–20 %	11	22.9	1	20.0	$p > 0.05$
More than 20 %	1	2.1	3	60.0	$p < 0.001$
Total	48	100	5	100	

Table 87.4 Diagnostic table of disturbance of lift height

Disturbance of lift height (x_2^i)	Number of observations		Probabilities		Certainty ratio	DC
	oper.	non-oper.	$P(x_2^i/A_1)$	$P(x_2^i/A_2)$		
0–10 %	36	1	0.75	0.20	3.75	5.74
10–20 %	11	1	0.229	0.20	1.146	0.59
More than 20 %	1	3	0.021	0.60	0.035	0.00
Total	48	5	1	1		

Table 87.5 Diagnostic table of productivity decrease

Productivity decrease (x_3^i)	In oper. state ($n = 48$)		In non oper. state ($n = 6$)		Certainty difference
	abs.	%	abs.	%	
0–10 %	38	79.2	1	16.7	$p < 0.001$
10–30 %	9	18.8	3	50.0	$p < 0.001$
30 %	1	2.1	2	33.3	$p < 0.05$
	48	100	6	100	

Table 87.6 Please write your table caption here

Productivity decrease (x_3^i)	Number of observations		Probabilities		Likelihood probability	DC
	oper.	non oper.	$P(x_3^i/A_1)$	$P(x_3^i/A_2)$		
0–10 %	38	1	0.792	0.167	4.75	6.77
10–30 %	9	3	0.188	0.500	0.38	−4.26
More than 30 %	1	2	0.021	0.333	0.06	−12.04
Total	48	6	1	1		

Table 87.7 The indicator

	Indicator (x_j)	Gradations of indicator	$P(x_j^i/A_1)$	$P(x_j^i/A_2)$
1	State of the pump unit	Existence of abrasive particles	0.167	0.815
		Planned serviceability was not performed	0.479	0.074
		Other factors related to operation	0.354	0.111
2	Disturbance of lift height	0–10 %	0.75	0.20
		10–20 %	0.229	0.20
		More than 20 %	0.021	0.60
3	Productivity decrease of the pump system	0–10 %	0.792	0.167
		10–30 %	0.188	0.500
		More than 30 %	0.021	0.333

Thus, all indicators for applying formula (87.4) are found (Table 87.7).

Further, taking into account the above tables, by the Bayes formula we can calculate the probabilities of outcomes of indicators:

$$P(A_1/x_1^i, x_2^i, x_3^i) = \frac{0.56 \cdot \prod_{j=1}^{3} P(x_j^i/A_1)}{0.56 \cdot \prod_{j=1}^{3} P(x_j^i/A_1) + 0.44 \cdot \prod_{j=1}^{3} P(x_j^i/A_2)}, \tag{87.4}$$

$$P(A_2/x_1^i, x_2^i, x_3^i) = \frac{0.44 \cdot \prod_{j=1}^{3} P(x_j^i/A_2)}{0.56 \cdot \prod\limits_{j=1}^{3} P(x_j^i/A_1) + 0.44 \cdot \prod\limits_{j=1}^{3} P(x_j^i/A_2)}, \tag{87.5}$$

where are gradations of indicators. The values and were calculated by above data. The results are given in Table 87.1.

Furthermore, the method of successive diagnostic procedure may be used, where DC are summed to achieve one of two diagnostic thresholds proceeding from previously chosen admissible level of diagnostic errors:

$$10\lg\frac{\alpha}{1-\beta} < \sum_i (x_j^i) + \sum_i . (x_j^i) < 10\lg\frac{1-\alpha}{\beta}, \tag{87.6}$$

$$\text{Thereshold } A = 10\lg\frac{1-\alpha}{\beta},$$

$$\text{Thereshold } B = 10\lg\frac{\alpha}{1-\beta}.$$

where α is the first order error probability (instead of output, the output is predicted), β is the second order error probability (false prediction, when in reality output). The quantities of threshold sums of DC at different admissible percent of errors are given in a special table.

The special DC is calculated by the formula:

$$DC_{spec.} = 10\lg\frac{P(A_1/x_j^i)}{P(A_2/x_j^i)} \tag{87.7}$$

87.4 Examples

Example 87.1 At subsequent planned inspection of the state of the pump station there were revealed: existence of abrasive particles, disturbance of lift height by 3 %, productivity decrease of the pump station 12.5 %, disturbance of operation rules specified in the instruction. Taking these facts into account in formulas (87.4) and (87.5), we get that probability of no-failure operation of the pump station under these conditions equals 0.353; probability of stoppage $C0.647$. This result gives ground to take urgent measures on removing shortcomings.

Example 87.2 When checking the state of the well and pump station there were revealed: the planned service-ability was not performed, disturbance of lift height by 12.5 %, productivity decrease of the pump station by 14.6 %. By formulas (87.4) and (87.5) we get that probability of no-failure operation of the pump station under these conditions equals 0.84; probability of stoppage $C0.16$.

Taking into account the results of calculations, shortcomings were removed by the staff and the station operated without a failure in the course of planned period of time.

87.5 Conclusions

(1)Application of the Bayes formula admits to estimate real state in pump stations in due time, to take urgent measures on removing malfunctions and provide no-failure operation of a station in the course of demanded period of time.

(2) Periodically controlling the state of pump stations by using the Bayes' formula, one can previously get necessary spare parts in order to remove malfunctions at planned stoppages of pump stations.

References

1. Afandiyev G, Khalilzade R, Hasanov R (2003) Analysis of factors influencing on results of surgical treatment of brain hemorrhage. Az Med J 1(4):71–74 (in Russian)
2. Gmurman V (2010) Theory of probability and mathematical statistics, 12th edn. Textbook, (in Russian)
3. Gubler E (1978) Calculation methods and analysis and recognition of pathological processes. L. Medicina, (in Russian)
4. Sharov V (2013) Application of bayes method for specifying probabilities of events in automated prognostic system and prevention of aviation accidents. J Control Large Syst. Collect Pap 5(43):240–253 (in Russian)

Part VI
Project Management

Chapter 88
Advances in Hybrid Metaheuristics for Stochastic Manufacturing Scheduling: Part I Models and Methods

Mitsuo Gen, Xinchang Hao and Wenqiang Zhang

Abstract Scheduling plays a very important role in the intelligent manufacturing system, where it can have a major impact on the productivity of a production process. However, it is very difficult to find an optimal solution for scheduling problems since most of them fall into the class of NP-hard problem. Because real world manufacturing problems often contain nonlinearities, multiple objectives conflicting each other and also uncertainties that are too complex to be modeled analytically. In these scenarios, hybrid metaheuristics based optimization is a powerful tool to determine optimal system settings to the stochastic manufacturing scheduling problems. Evolutionary algorithm (EA) in hybrid metaheuristics is a generic population-based metaheuristic optimization algorithm, which can find compromised optimal solutions well for a complicated scheduling problem. This paper surveys recent hybrid metaheuristics such as hybrid sampling strategy-based EA(HSS-EA) which combines vector evaluated genetic algorithm (VEGA) and a new archive maintenance strategy to preserve both the convergence rate and the distribution performance, and multi-objective estimation of distribution algorithm (MoEDA) which builds and samples explicit probabilistic model for the distribution of promising candidate solutions found so far and use the constructed model to guide further search behavior.

M. Gen (✉)
Fuzzy Logic Systems Institute, Tokyo University of Science,
Tokyo, Japan
e-mail: gen@flsi.or.jp

X. Hao
Graduate School of Information, Production and Systems, Waseda University,
Tokyo, Japan

W. Zhang
College of Information Science and Engineering, Henan
University of Technology, Henan, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_88

Keywords Multi-objective optimization problem (MOP) · Multi-objective evolutionary algorithm (MoEA) · Stochastic MOP (S-MOP) · Estimation of distribution algorithm (EDA) · Hybrid sampling strategy-based EA (HSS-EA)

88.1 Introduction

In real world manufacturing systems there are many combinatorial optimization problems (COP) imposing on more complex issues, such as complex structure, nonlinear constraints, and multiple objectives to be handled simultaneously. Manufacturing scheduling is one of the important and complex COP models, where it can have a major impact on the productivity of a production process. Moreover, the COP models make the problem intractable to the traditional optimization techniques because most of scheduling problems fall into the class of NP-hard combinatorial problems [20, 21]. In order to develop effective and efficient solution algorithms that are in a sense good, i.e., whose computational time is small as within 3 min, or at least reasonable for NP-hard combinatorial problems met in practice, we have to consider:

- Quality of solution,
- Computational time and
- Effectiveness of the nondominated solutions for multiobjective optimization problem (MOP) consisting multiple and conflicting objectives.

They surveyed multi-objective hybrid genetic algorithms (MoHGA) for manufacturing scheduling problems and applied to real world problems for the hard disc device (HDD) and the thin-film transistor-liquid crystal display (TFT-LCD) manufacturing systems, respectively [17]. Recently Gutjahr and Pichler [25] surveyed a S-MOP methods based on non-scaling for risk-neutral decision makers.

Over the past sixty years, a great number of researches have been conducted on a jobshop scheduling problem (JSP), which is one basic model of manufacturing scheduling problems and very popular in manufacturing systems. As one of famous combinatorial optimization problems is known as NP-hard [6, 15, 18, 42], generally JSP aims at minimizing the makespan with the considering of precedence and resource constraints. For conventional JSP model, there is often making the assumptions in traditional machine scheduling theory is that all time parameters are known exactly and in deterministic values. However, in manufacturing systems, uncertainties are often encountered. This uncertainty may stem from a number of possible sources [34]: operation may take more or less time than originally estimated, resources may become unavailable, due dates may have to be changed, or new orders may have to be incorporated, etc. At present, the common mathematic methods for modeling scheduling problem with uncertainties are stochastic programming, fuzzy programming, rough sets, grey programming and interval theory [26]. And in stochastic programming, the parameters are initially described in terms of probability distributions, and the problem is named as the stochastic scheduling [38].

An assembly line is a typical manufacturing process consisting of various tasks in which interchangeable parts are added to a product in a sequential manner at a station to produce a final product. Most of the work related to the assembly lines concentrate on the assembly line balancing (ALB) which deals with the allocation of the tasks among stations so that the precedence relations among them are not violated and a given objective function is optimized [56]. From the view point of the real ALB systems, multi-objective ALB with stochastic processing time (S-MoALB) is an important and practical topic from traditional ALB problem involving conflicting criteria such as the cycle time, variation of workload, and/or the processing cost under uncertain manufacturing environment [59].

The stochastic resource-constrained project scheduling problem (S-RcPSP) aims at scheduling project activities with uncertainty in order to minimize the expected project duration subject to zero-lag finish-start precedence constraints and renewable resource constraints [34, 41]. As one kind of stochastic project scheduling problems (S-PSP), a significant amount of results have been achieved on the resource constrained project scheduling with uncertain durations. Igelmund and Radermacher [37] firstly developed pre-selective policies to minimize the expected overall project cost, dealing with a stochastic version of the optimization problem for project networks under resource constraints.

The paper is organized as follows: Sect. 88.2 reviews the literature of recent research works on stochastic jobshop scheduling problems (S-JSP), stochastic assembly line balancing (S-ALB) models and stochastic resource constrained project scheduling problems (S-RcPSP). Section 88.3 presents the stochastic models of multi-objective optimization problem (S-MOP) and hybrid metaheuristics such as the multi-objective hybrid evolutionary algorithm (S-MoEA)with fitness assignment mechanism and frame work of the estimation of distribution algorithm (EDA) and multi-objective EDA (MoEDA). In Sect. 88.4 the conclusion and future work are given.

88.2 Literature Review

The jobshop scheduling problem (JSP) is one basic model of manufacturing scheduling problems and very popular in manufacturing systems. Gen and Cheng [14, 15] surveyed a genetic algorithm (GA) for solving JSP and Cheng et al. [5, 6] reported a tutorial survey on representation and hybrid genetic search strategies, respectively for JSP model. Flexible jobshop scheduling problem (FJSP) is an extension of the traditional JSP and provides a closer approximation to real scheduling problems. Gao et al. [11–13] proposed hybrid genetic algorithms (HGA) for scheduling jobs and maintenance in FJSP, HGA with bottleneck shifting for multi-objective FJSP (MoFJSP) and HGA with variable neighborhood descent algorithm for the multi-objective FJSP. Gen et al. [19] proposed multistage-based genetic algorithm with bottleneck shifting for solving the multi-objective FJSP problem.Meanwhile, there are some novel intelligent evolutionary computation methods are carried out. Tavakkoli-Moghaddam et al. [52] proposed a hybrid method using a neural network approach and a simulated annealing algorithm in 2 stages, in order to produce the optimal/near-optimal solution to the stochastic jobshop scheduling problem (S-JSP). In real-world problem, most of the jobshop scheduling problems is the stochastic scheduling problems. As one of the newest issues, more and more attention is spent on the problem with random processing time. As a result, in the last several decades, a significant amount of results have been achieved on the stochastic jobshop scheduling problem. Liu, Wang and Jin [47] proposed an approach named PSOSAHT, which hybrid with particle swarm optimization (PSO), simulated annealing (SA) and hypothesis test (HT) for stochastic flowshop scheduling problem (S-FSP) with uncertain processing time.

Zhou, Nee and Lee [60] proposed an ant colony optimization (ACO) algorithm with different levels of machine utilizations, processing time distributions, and performance measures. Gu et al. [26] proposed a novel parallel quantum genetic algorithm (NPQGA) for the S-JSP with the objective of minimizing the expected value of makespan. Gholami and Zandieh [23] integrated simulation into genetic algorithm to the dynamic scheduling of a flexible jobshop with the objectives of minimizing expected makespan and mean tardiness. Lei [43, 44] developed a particle swarm optimization (PSO) for multi-objective fuzzy jobshop scheduling problems and an efficient decomposition-integration genetic algorithm (DIGA) to minimize the maximum fuzzy completion time. Horng, Lin and Yang [36] proposed an evolutionary algorithm ESOO as embedding evolutionary strategy (ES) in ordinal optimization (OO) to solve for a good enough schedule with the objective of minimizing the expected sum of storage expenses and tardiness penalties.

Hao et al. [29] proposed effective estimation of distribution algorithm (EDA) for solving S-JSP with the uncertainty of processing time, to minimize the expected average makespan within a reasonable amount of calculation time. Recently Hao et al. [28] proposed the effective multi-objective EDA for solving bicriteria stochastic JSP with probabilistic processing time to minimize the expected makespan and total tardiness and demonstrated the performance regarding convergent speed and optimization quality. Hao et al. [31] proposed effective Markov network based EDA for solving a stochastic flexible jobshop scheduling problems under Uncertainty (S-FJSP). The Table 88.1 is the classification for the stochastic JSP models.

A number of reviews for stochastic assembly line balancing (S-ALB) models have been published on single objective [10, 33, 48] and multi-objective optimization [4, 27]. Fazlollahtabar et al. [10] proposed a model based on the rank positional weight algorithm by considering stochastic activity task times; two other methodologies of normal distribution integration and Monte Carlo simulation were developed. Nazarian and Ko [48] proposed a new method and model for a robust line design to overcome inefficient and unsystematic determination of the buffer time, which was based on cycle time violation and manufacturing time variations. Hazír and Dolgui [33] presented two robust optimization models with interval and operation uncertainty at each station. They proposed a decomposition-based algorithm combined

Table 88.1 The published journal paper for solving JSP under uncertainty

Uncertainty	Modelling technique	Objectives	Authors (year published)	Methodology
Processing time and machine breakdown	Stochastic	Total weighted tardiness	Kutanoglu and Sabuncuoglu (2001) [39]	Simulation methods
Processing time	Stochastic	Penalty costs	Golenko-Ginzburg and Gonik (2002) [24]	Decision-making rules
Processing time	Stochastic	Makespan	Yoshitomi and Yamaguchi (2003) [55]	GA and Monte Carlo method
Processing time	Stochastic	Makespan	Tavakkoli-Moghaddam et al. (2005) [52]	Co-evolutionary Quantum GA
Processing time	Stochastic	Makespan	Liu, Wang, and Jin (2005) [47]	Hybrid PSO
Processing time	Stochastic	Expected makespan and total tardiness	Lei and Xiong (2007) [46]	MoGA
Processing time and dual date	Fuzzy rule	Expected makespan	Lei (2008) [43]	MoPSO
Lot-size and priority of the job	Fuzzy sets	Average weighted tardiness	Petrovic et al. (2008) [49]	MoGA
Machine unavailability and breakdown	Stochastic	Average makespan	Hasan, Sarker, and Essam (2011) [32]	HGA
Processing time	Stochastic	Makespan	Azadeh, Negahban, and Moghaddam (2011) [3]	Simulation-ANN algorithm
Processing time	Stochastic	Makespan	Lei (2012) [45]	GA
Processing time	Stochastic	Expected total weighted tardiness	Zhang, Song and Wu (2012) [57]	Hybrid PSO
Processing time	Stochastic	Expected makespan	Hao, Lin, Gen and Ohno (2013) [29]	EDA
Processing time	Stochastic	Expected sum of earliness and tardiness	Yang, Lv, Xia, Sun and Wang (2014) [54]	Hybrid ES
Processing time	Stochastic	Expected makespan and total tardiness	Hao, Gen, Lin and Suer (2015) [28]	Hybrid MoEDA

with enhancement strategies to solve optimally large-scale instances of assembly line problems. The above works mostly focus on single objective optimization. For multi-objective optimization in uncertain environments, Cakir et al. [4] developed a hybrid-simulated annealing algorithm. They used multi-nomial probability mass functions, repair algorithms, and diversification strategies to deal with the single-model S-ALB problem with parallel stations. Hamta et al. [27] produced a bi-criteria nonlinear integer programming model to combine two inconsistent objective functions, and incorporated a genetic algorithm to handle ALB with flexible task times. Although single-objective, stochastic, assembly-line balancing problems have been investigated by various researchers, there remains a lack of optimization methodology for multi-objective stochastic problems.

For solving a stochastic project scheduling problems (S-PSP), Stork [51] implemented a branch-and-bound algorithm (BBA) to compute optimal ES-, PRS-, LIN- and JBP-policies, using two branching schemes, lower bound calculation and various dominance rules. In the field of the heuristic algorithm, Dimitri and Gonik [9] presented a newly developed resource constrained scheduling model for a PERT type project, where the duration of an activity is a random variable with given density function and a pre-given lower and upper bound on the activity duration is available. Al-Fawzan and Haouari [1] introduced the concept of schedule robustness and developed a bi-objective resource-constrained project scheduling (BoRcPSP) model with robustness maximization along with makespan minimization, with usage of Tabu search (TS) algorithm to generate an approximate set of efficient solutions. Van de Vonder et al. [53] discussed trade-off between the quality robustness (project duration) and solution robustness (deviation between the planned and realized start times of the projected schedule) based on analysis of the results of a simulation experiments. Artigues et al. [2] developed and implemented a scenario-relaxation algorithm and a scenario-relaxation-based heuristic, based a theoretical framework that enables the decision maker to produce solutions in which it had a reasonably good objective value under any likely input data scenario.

88.3 Stochastic MOP Model and Hybrid Metaheuristics

88.3.1 Stochastic Multiobjective Optimization Problem

Real world manufacturing problems often contain nonlinearities, multiple objectives conflicting each other and also uncertainties that are too complex to be modeled analytically. In these scenarios, metaheuristics is a powerful tool to determine optimal solution to the problem [35]. The stochastic model has been observed in a large range of application fields such as finance, energy, transportation logistics, facility location, manufacturing and production planning, supply chain management, humanitarian logistics, telecommunication, health care management or project management [25].

A stochastic multi-objective optimization problem (S-MOP) arises in the design, modeling, and planning of many real complex systems in the areas of industrial production, urban transportation, capital budgeting, forest management, reservoir management, layout and landscaping of new cities, energy distribution, etc. [25]. Since the 1990s, EAs have been received considerable attention as a novel approach to MOPs, resulting in a fresh body of research and applications known as evolutionary multi-objective optimization [7, 15]. Without loss of generality, a stochastic MOP model with q objective functions conflicting each other with n decision variables and random variables subject to m constraints can be formally represented as follows:

$$\begin{aligned} &\max \left\{z_1 = f_1(\mathbf{x},\ Y), z_2 = f_2(\mathbf{x},\ Y), \ldots, z_q = f_q(\mathbf{x},\ Y)\right\} \\ &\text{s. t. } g_i(\mathbf{x},\ Y) \leq 0, \quad i = 1, 2, \ldots, m \\ &\quad \mathbf{x} \in \mathrm{R}^n, \quad Y: \quad \text{vector of random variables.} \end{aligned} \tag{88.1}$$

The each objective function $f_j(\mathbf{x}, \mathbf{Y})$ is shorthand for the real-valued random variable assigning to each so-called scenario $\omega \in \mathbf{\Omega}$ the value $f_j(\mathbf{x}, \mathbf{Y}(\omega))$; therein, $\mathbf{\Omega}$ is the sample space, i.e., decision space. Each scenario ω determines a realization of the random variable $Y(\omega)$ and therefore also of the random variable $f_j(\mathbf{x}, \mathbf{Y}(\omega))$. Since $Y = Y(\omega)$ is completely determined by the scenario ω, we will simply write $f(\mathbf{x}, \mathbf{Y}(\omega))$ instead of $f(\mathbf{x}, \mathbf{Y}(\omega))$ and by taking the expectation operator $E[f(.)]$ for each function the stochastic MOP model reformulated as follows:

$$\begin{aligned} &\max\left\{\mathrm{E}[f_1(\mathbf{x},\ \boldsymbol{\omega})\},\ \mathrm{E}[f_2(\mathbf{x},\ \boldsymbol{\omega})\}, \ldots,\ E[f_q(\mathbf{x},\ \boldsymbol{\omega})]\right\} \\ &\text{s.t. } \mathrm{E}[g_i(\mathbf{x},\ \boldsymbol{\omega})] \leq 0, \quad i = 1, 2, \ldots, m \\ &\quad \mathbf{x} \in \mathrm{R}^n,\ \ \boldsymbol{\omega} \in \mathbf{\Omega}. \end{aligned} \tag{88.2}$$

We sometimes graph the MOP problem in both decision space and criterion space. S is used to denote the feasible region in the decision space and Z is used to denote the feasible region in the criterion space, respectively as follows:

$$S = \left\{\mathbf{y} \in \mathrm{R}^n \mid \mathrm{E}[g_i(\mathbf{x},\ \boldsymbol{\omega})] \leq 0,\ \ i = 1, 2, \ldots m\right\}, \tag{88.3}$$

$$Z = \left\{\mathbf{z} \in \mathrm{R}^q \left| \mathrm{E}[f_1(\mathbf{y},\ \boldsymbol{\omega})\},\ \mathrm{E}[f_2(\mathbf{y},\ \boldsymbol{\omega})\}, \ldots,\ E[f_q(\mathbf{y},\ \boldsymbol{\omega})], \mathbf{y} \in S\right.\right\}, \tag{88.4}$$

where $\mathbf{z} \in R^q$ is a vector of values of q objective functions. In the other words, Z is the set of images of all points in S. Although S is confined to the nonnegative region of R^n and Z is not necessarily confined to the nonnegative region of R^q. There usually exists a set of solutions for the multiple objective cases which cannot be simply compared with each other. Such kind of solutions are called non-dominated solutions or Pareto optimal solutions, for which no improvement in any objective function is possible without sacrificing on at least one of other objectives.

Definition 88.1 For a given point $z^0 \in Z$, it is non-dominated if and only if there does not exist another point $z \in Z$ such that for the maximization case,

$$\begin{aligned} &z_k > z_k^0, \quad \text{for some } \ k \in \{1, 2, \ldots q\} \\ &z_l \geq z_l^0, \quad \text{for some } \ l \neq k, \end{aligned} \tag{88.5}$$

where z^0 is a dominated point in the criterion space Z with q objective functions.

88.3.2 Fitness Assignment Function by HSS-EA

When applying the EAs to solve a given multi-objective optimization problem (MOP), it is necessary to refine upon each of the major components of EAs, such as encoding/decoding methods, recombination operators, fitness assignment, selection operators, and constraints handling, and so on, in order to obtain a best Pareto optimal solution to the given MOP problem. One of special important issues in the MOP is fitness assignment mechanism for treating multiple and conflicting objective functions. Although most fitness assignments are just different approach and suitable to different cases of MOP models, we classify fitness assignment algorithms according to proposed years of different approaches [16]:

- Vector evaluated genetic algorithm (VEGA; [50])
- Adaptive-weight genetic algorithm (AWGA; [15])
- Strength Pareto evolutionary algorithm II (SPEA 2; [62])
- Non-dominated sorting genetic algorithm II (NSGA II; [7])
- Interactive adaptive-weight genetic algorithm (i-AWGA; [18])
- Hybrid sampling strategy-based EA (HSS-EA; [58])

In this paper, a new fitness function based on a new Pareto dominating and dominated relationship-based fitness function (PDDR-FF) is proposed to evaluate the fit-ness of each chromosome [59]. The fitness function value of a chromosome is calculated by the following function:

$$\text{eval}\,(S_i) = B(S_i) + \frac{1}{D\,(S_i) + 1}, \tag{88.6}$$

where $B(S_i)$ is the number of chromosomes dominating S_i which is defined as the Eq. (88.12):

$$B(S_i) = \left|\left\{S_j \,\middle|\, S_j \prec S_i,\, j = 1, 2, \ldots, \text{popSize}\right\},\right|, \tag{88.7}$$

where $D(S_i)$ is the number of chromosomes dominated by as defining the Eq. (88.13), popSize is the size of the population.

$$D(S_i) = \left|\left\{S_j \,\middle|\, S_i \prec S_j,\, j = 1, 2, \ldots, \text{popSize}\right\}\right|. \tag{88.8}$$

The smaller the PDDR-FF value means that the more chromosomes dominated by S_i and the less chromosomes dominate S_i. Therefore, the smaller the PDDR-FF value, the better. And besides, PDDR-FF can also set clear differences between the non-dominated chromosome and the dominant chromosome. If a chromosome is a non-dominant chromosome, the fitness function value is not more than 1. Furthermore, even if it is not a dominant chromosome, the chromosome with different numbers of domination is given a different fitness function values. It is obvious that the fitness function value (close to 0) of the non-dominated chromosomes locating near the central area of the Pareto front having big domination area is smaller than the value (close to 1) of the chromosome in the edge region.

88.3.3 Framework of Multi-objective EDA

The estimation of distribution algorithm (EDA) is a class of population-based optimization algorithms that extracts statistical information from the population of solutions and uses it to generate new solutions instead of the crossover and mutation operators [40]. The algorithm starts by generating a population solution. A set of solutions promising data is selected from the population using a selection method, and the promising data is used to estimate the probability model. Finally, the new candidate solutions are incorporated into a solution pool, which keeps these chromosomes contribute to the makeup of promising data. The iteration will continue until the predefined termination criteria are met. The pseudo-code for the EDA main routine is presented in Fig. 88.1.

For traditional EAs, the representation of a chromosome for each chromosome is generated by mapping the decision space into the search space or directly encoding the decision variables. Each position in a probability vector indicates the distribution of probability regarding each variable. Generally, for discrete variables X, the domain of X is a set of predefined values (x). When prior knowledge of distribution is not assumed, the distribution of random variable X has the same equal probability; the initialization is as follows:

```
procedure: EDA main routine
input: problem data, EDA parameters
output: the best solutions S_best
begin
    t ← 0;
    initialize population Pop(t) by encoding routine and probability model P(t);
    evaluate Pop(t) by decoding routine and keep the best solution S_best;
  while (not terminating condition) do
       select supPop from Pop(t);
       estimate P(t+1) from supPop and P(t);
       create newPop Pop(t+1) from P(t+1);
       evaluate Pop(t) by decoding routine andupdate the best solution S_best;
       reproduce Pop(t+1) by replacing popSz x elimRate worse items among Pop(t+1) with
supPop;
     t ← t + 1;
     end
     output the best solution S_best
end;
```

Fig. 88.1 The procedure of EDA main routine

$$P_{t=0}(X) = \frac{1}{|X|}, \tag{88.9}$$

where $|X|$ denotes the number of values in the set of domain X.

After the initialization of EDA, probability sample new alternative solutions, and the new solutions are evaluated according to a specific system objective. EDA collects all new alternative solutions and replaces the inferior solutions in the promising data. The probability distribution of X can be estimated as follows:

$$B_t(X = x) = ((X = x) + \frac{1}{|X|})/(prSize + \frac{1}{|X|}), \tag{88.10}$$

where $(X = x)$ denotes the number of instances in promising solutions with variable $X = x$, and represents the low bound to the probability of X.

The distribution probability of X in the probability vector is learned toward the estimated distribution of promising data, as follows:

$$P_{t+1}(X = x) = (1 - \alpha)P_t(X = x) + \alpha B_t(X = x), \tag{88.11}$$

where α denotes the learning rate from the current promising solutions; in particular, for $\alpha = 1$, the probability distribution is completely reconstructed by the current promising solutions. To maintain the diversity of sampling, the distribution probability of X is updated toward the estimation distribution. The distribution can be tuned with probability p_m of the mutation, and the mutation is performed using the following definition:

$$P_{t+1}(X = x) = \frac{P_t(X = x) + \lambda_m}{\sum_{x' \in X\{x\}} \max\left(P_t(x) - \frac{\lambda_m}{|X|-1}, \varepsilon) + (P_t(X = x) + \lambda_m\right)}, \tag{88.12}$$

where λ_m is the mutation shift that controls the amount for the mutation operation, and ε is a small probability value to avoid the negative probability value. For S-JSP, The decision-making space is operation sequence. Therefore, the first probability model is to model the priority (importance) and the likelihood of adjacent operations in operation sequence. Let η_{ijl} be the number of times that job i appears before or in position l in the promising data D. It denotes the importance of the order of jobs. μ_{il} is the number of times that job i appears immediately after job i' when job i' is in position $l - 1$. μ_{il} indicates the importance of the similar blocks of jobs in the promising data D. Then, the probability for positioning job i in the lth position of the offspring for generation t is determined by

$$p_t(i, l) = \beta M(\eta_i l) + (1 - \beta)M(\mu_i l) \tag{88.13}$$

where

$$M(\eta_{il}) = 1 - \exp(-\eta_{ij} / \sum_{i' \in D} \eta_{i'j}) / (\sum_{i'' \in D} 1 - \exp(-\eta_{i''j} / \sum_{i' \in D} \eta_{i'j})),$$
$$M(\mu_{il}) = 1 - \exp(-\mu_{ij} / \sum_{i' \in D} \mu_{i'j}) / (\sum_{i'' \in D} 1 - \exp(-\mu_{i''j} / \sum_{i' \in D} \mu_{i'j})).$$

$M(\eta_{il})$ moreover, $M(\mu_{il})$ are completeness measures for importance of the order jobs and similar blocks, respectively. β is behavior coefficient, which is used to adjust the preference on which covering percentage we want to have a good discrimination.

Since Giffler–Thompson-based decoding algorithm does not consider the internal idle time, the solution is always not the optimal. For improving the objective, neighbourhood search is employed to improve the objectives in the hybrid MoEDA. The priority (importance) of jobs on each machine is modeled as statistical inference. Similar to η_{jl}, let η_{jlm} be the number of times that the job i appears before or in

```
procedure: MoEDA main routine
input: problem data, EDA parameters (prRate: rate of the promising kept by MoEDA, elim Rate:
    elimination rate of the keeping promising solutions)
output: the best Pareto solutions S_best
begin
    t ← 0;
    initialize population Pop(t) by encoding routine and probability model P(x_i);
    calculate objective f_k(Pop), k=1,…,q by decoding routine;
    create Pareto optimal solutions E(Pop) by nondominated routine;
    calculate fitnesseval(Pop) by HSS-EA routine and keep the best Pareto solution S_best;
    while (not terminating condition) do
        select supPopD from Pop(t) consisting of popSize x prRate solutions;
        estimate P(x_i) for each variable X_i over the set D and sample candidates based on P(t);
        create newPop Pop(t+1) from supPop and P(x_i);
        calculate objective f_k(Pop), k=1,…,q by decoding routine;
        update Pareto optimal solutions E(Pop) by nondominated routine;
        calculate fitness eval(Pop) by HSS-EA routine and update best Pareto solution S_best;
        reproduce Pop(t+1) by replacing popSz x elimRate worse items among Pop(t+1) with
supPop;
        t ← t + 1;
    end
    output the best Pareto solution S_best
end;
```

Fig. 88.2 The main routine of the MoEDA in the pseudo-code position l on machine m in the promising data D, and μ_{ilm} indicates the importance of the similar blocks of jobs on machine m in the promising data D. Similarly, the probability for positioning job i in the lth position on machine m of the offspring for generation t is determined by

$$p_t(i, l|m) = \beta M(\eta_{ilm}) + (1 - \beta)M(\mu_{ilm}). \tag{88.14}$$

$M(\eta_{ilm})$ moreover, $M(\mu_{ilm})$ are completeness measures for importance of the order jobs and similar blocks on machine m, respectively. The main routine of the multi-objective EDA (MoEDA) in the pseudo-code is designated as shown in Fig. 88.2.

88.4 Conclusions

Scheduling in real world plays a very important role in the integrated manufacturing system, where it can have a major impact on the productivity of a production process. However, it is very difficult to find an optimal solution for manufacturing scheduling problems since most of them fall into the class of NP-hard problem. Because real world manufacturing problems often contain nonlinearities, multiple objectives conflicting each other and also uncertainties that are too complex to be modeled analytically. In these environmental situation, hybrid metaheuristics based optimization technique is a powerful tool to find optimal system settings to the stochastic manufacturing scheduling problems. Evolutionary algorithm (EA) in hybrid metaheuristics is a generic population-based metaheuristic algorithm, which can find a best compromised optimal solutions among a lot of Pareto optimal solutions to multi-objective optimization problems (MOPs) well for a complicated nonlinear scheduling problem with multiple objectives conflicting each other.

This paper surveyed recent hybrid metaheuristics such as hybrid sampling strategy-based EA (HSS-EA) which combines vector evaluated genetic algorithm and a new archive maintenance strategy to preserve both the convergence rate and the distribution performance, and multi-objective estimation of distribution algorithm (MoEDA) which builds and samples explicit probabilistic model for the distribution of promising candidate solutions found so far and use the constructed model to guide further search behavior. For demonstrating computational experiments on stochastic multi-objective jobshop scheduling problem (S-MoJSP) by MoEDA, stochastic multi-objective assembly line balancing (S-MoALB) problem by HSS-EA and stochastic multi-objective resource-constrained project scheduling problem (S-MmRcPSP) by MoEDA, the effectiveness and efficiency are demonstrated in the concatenated paper Part II [22].

Acknowledgments This work is partly supported by the Grant-in-Aid for Scientific Research (C) of Japan Society of Promotion of Science (JSPS): No. 15K00357, National Science Foundation of China: No.61572100, Fundamental Research Funds for the Central Universities No. DUT15QY10, National Natural Science Foundation of China: No. U1304609, the Key Young Teacher training

Program of Henan University of Technology, the Fundamental Research Funds for the Henan Provincial Colleges and Universities No. 2014YWQQ12, and Research Funds for Key Laboratory of Grain Information Processing and Control (Henan University of Technology), Ministry of Education, China.

References

1. Al-Fawzan MA, Haouari M (2005) A bi-objective model for robust resource-constrained project scheduling. Int J Prod Econ 96:175–187
2. Artigues C, Leus R, Nobibon FT (2013) Robust optimization for resource-constrained project scheduling with uncertain activity durations. Flex Serv Manuf 25:175–205
3. Azadeh A, Negahban A, Moghaddam M (2011) A hybrid computer simulation-artificial neural network algorithm for optimization of dispatching rule selection in stochastic job shop scheduling problems. Int J Prod Res 50(2):551–566
4. Cakir B, Altiparmak F, Dengiz B (2011) Multi-objective optimization of a stochastic assembly line balancing: a hybrid simulated annealing algorithm. Comput Indus Eng 60(3):376–384
5. Cheng R, Gen M, Tsujimura Y (1999) A tutorial survey of job-shop scheduling problems usinggenetic algorithms: part II. hybrid genetic search strategies. Comput Indus Eng 36(2):343–364
6. Cheng R, Gen M, Tsujimura Y (1996) A tutorial survey of job-shop scheduling problems usinggenetic algorithms: part I. Representation. Comput Indus Eng 30(4):983–997
7. Deb K (2001) Multi-objective optimization using evolutionary algorithms. Wiley, Chichester
8. Deb K, Pratap A et al (2002) A fast and elitist multiobjective genetic algorithm: NSGA-II. IEEE Trans Evol Comput 6(2):182–197
9. Dimitri GG, Gonik A (1997) Stochastic network project scheduling with non-consumable limited resources. Int J Prod Econ 48:29–37
10. Fazlollahtabar H, Hajmohammadi H, Es'haghzadeh A (2011) A heuristic methodology for assembly line balancing considering stochastic time and validity testing. Int J Adv Manuf Technol 52:311–320
11. Gao J, Gen M et al (2007) A hybrid of genetic algorithm and bottleneck shifting for multiobjective flexible job shop scheduling problems. Comput Indus Eng 53:149–162
12. Gao J, Gen M, Sun L (2006) Scheduling jobs and maintenances in flexible job shop with a hybrid genetic algorithm. J Intell Manuf 17:493–507
13. Gao J, Sun L, Gen M (2008) A hybrid genetic and variable neighborhood descent algorithm for flexible job shop scheduling problems. Comput Oper Res 35:2892–2907
14. Gen M, Cheng R (1997) Genetic algorithms and engineering design. Wiley, New York
15. Gen M, Cheng R (2000) Genetic algorithms and engineering optimization. Wiley, London
16. Gen M, Lin L (2014) Multiobjective evolutionary algorithm for manufacturing scheduling problems: state-of-the-art survey. J Intell Manuf 25(5):849–866
17. Gen M, Zhang WQ (2015) Recent advance in hybrid metaheuristics for multiobjective manufacturing scheduling. In: Proceedings of the international conference on computers and industrial engineering, Metz, France
18. Gen M, Cheng R, Lin L (2008) Network models and optimization: multiple genetic algorithm approach. Wiley, New York
19. Gen M, Gao J, Lin L (2009) Multistage-based genetic algorithm for flexible job-shop scheduling problem. Intelligent and evolutionary systems, SCI 187, pp 183–196, Springer, Berlin
20. Gen M, Lin L, Zhang WQ (2015) Multiobjective hybrid genetic algorithms for manufacturing scheduling: Part I models and algorithms. Adv Intell Syst Comput 362:3–25
21. Gen M, Zhang WQ, Lin L (2015) Multiobjective hybrid genetic algorithms for manufacturing scheduling: Part II case studies of HDD and TFT-LCD. Adv Intell Syst Comput 362:27–54

22. Gen M, Zhang WQ, Hao XC (2016) Advances in hybrid metaheuristics for stochastic manufacturing scheduling: Part II case studies, In: Proceedings of the 10th international conference on management science and engineering management, Bake
23. Gholami M, Zandieh M (2009) Integrating simulation and genetic algorithm to schedule a dynamic flexible jobshop. J Intell Manuf 20:481–498
24. Golenko-Ginzburg D, Gonik A (2002) Optimal job-shop scheduling with random operations and cost objectives. Int J Prod Econ 76(2):147–157
25. Gutjahr WA, Pichler A (2016) Stochastic multi-objective optimization: a survey on non-scalarizing methods. Ann Oper Res 236:475–499
26. Gu J, Gu X, Gu M (2009) A novel parallel quantum genetic algorithm for stochastic jobshop scheduling. J Math Anal Appl 355:63–81
27. Hamta N, Fatemi Ghomi SMT et al (2011) Bicriteria assembly line balancing by considering flexible operation times. Appl Math Modell 35(12):5592–5608
28. Hao XC, Gen M et al (2015) Effective multiobjective EDA for bi-criteria stochastic job-shop scheduling problem. J Intell Manuf 8:1–13. doi:10.1007/s10845-014-1026-0
29. Hao XC, Lin L et al (2013) Effective estimation of distribution algorithm for Stochastic jobshop scheduling problem, Procedia Comp. Sci. 20:102–107
30. Hao XC, Lin L et al (2014) An effective Markov network based EDA for flexible job shop scheduling problems under uncertainty. In: Proceedings of the IEEE international conference on automation science and engineering, pp 131–136
31. Hao XC, Lin L, Gen M (2014) An effective multi-Objective EDA for robust resource constrained project scheduling with uncertain durations. Procedia Comput Sci 36:571–578
32. Hasan SMK, Sarker R, Essam D (2011) Genetic algorithm for job-shop scheduling with machine unavailability and breakdowns. J Int Found Prod Res 49(2):4999–5015
33. Hazír o, Dolgui A, (2013) Assembly line balancing under uncertainty: Robust optimization models and exact solution method. Comput Indus Eng 65(2):261–267
34. Herroelen W, Leus R (2005) Project scheduling under uncertainty: survey and research potentials. Eur J Oper Res 165:289–306
35. Hnaien F, Delorme X, Dolgui A (2010) Multi-objective optimization for inventory control in two-level assembly systems under uncertainty of lead times. Comput Oper Res 20:1835–1843
36. Horng SC, Lin SS, Yang FY (2012) Evolutionary algorithm for stochastic jobshop scheduling with random processing time. Expert Syst Appl 39:3603–3610
37. Igelmund G, Radermacher FJ (1983) Preselective strategies for the optimization of stochastic project networks under resource constraints. Networks 13:1–28
38. Kall P, Wallace SW (1994) Stochastic programming. Wiley, New York
39. Kutanoglu E, Sabuncuoglu I (2001) Experimental investigation of iterative simulation-based scheduling in a dynamic and stochastic job shop. J Manuf Syst 20(4):264–279
40. Larrañaga P, Lozano JA (2002) Estimation of distribution algorithms: a new tool for evolutionary computation. Springer, Berlin
41. Lawrence S (1984) Resource constrained project scheduling: an experimental investigation of heuristic scheduling techniques (supplement) Graduate School of Industrial Administration. Carnegie-Mellon University, Pittsburgh, PA
42. Lawler EL, Lenstra JK et al (1993) Sequencing and scheduling: algorithms and complexity. Handb Oper Res Manage Sci 4:445–522
43. Lei D (2008) Pareto archive particle swarm optimization for multiobjective fuzzy job shop scheduling problems. Int J Adv Manuf Technol 37(1):157–165
44. Lei D (2010) A genetic algorithm for flexible jobshop scheduling with fuzzy processing time. Int J Prod Res 48:2995–3013
45. Lei D (2012) Minimizing makespan for scheduling stochastic job shop with random breakdown. Appl Math Comput 218(24):11851–11858
46. Lei DM, Xiong H (2007) An efficient evolutionary algorithm for multi-objective stochastic job shop scheduling. In: Proceedings of the international conference on machine learning and cybernetics, pp 867–872

47. Liu B, Wang L, Jin Y (2005) Hybrid particle swarm optimization for flow shop scheduling with stochastic processing time. Comput Intell Secur LNCS 3801:630–637
48. Nazarian E, Ko J (2013) Robust manufacturing line design with controlled moderate robustness in bottleneck buffer time to manage stochastic inter-task times. J Manuf Syst 32(2):382–391
49. Petrovic S, Fayad C, Petrovic D, Burke E, Kendall G (2008) Fuzzy job shop scheduling with lot-sizing. Annal Oper Res 159(1):275–292
50. Schaffer J (1985) Multiple objective optimization with vector evaluated genetic algorithms. In: Proceedings of the 1st international conference on genetic algorithms, pp 93–100, Hillsdale, NJ
51. Stork F (2000) Branch-and-bound algorithms for stochastic resource-constrained project scheduling. Research Report No. 702, Technische Universitat Berlin
52. Tavakkoli-Moghaddam R, Jolai F et al (2005) A hybrid method for solving stochastic jobshop scheduling problems. Appl Math Comput 170:185–206
53. Van de Vonder S et al (2005) The use of buffers in project management: the trade-off between stability and makespan. Int J Prod Econ 97:227–240
54. Yang H, Lv Y et al (2014) Optimal computing budget allocation for ordinal optimization in solving stochastic job shop scheduling problems. Math Prob Eng 2014(6):1–10. doi:10.1155/2014/619254
55. Yoshitomi Y, Yamaguchi R (2003) A genetic algorithm and the Monte Carlo method for stochastic job-shop scheduling. Int Trans Oper Res 10(6):577–596
56. Zhang WQ, Gen M (2011) An efficient multiobjective genetic algorithm for mixedmodel assembly line balancing problem considering demand ratio-based cycle time. J Intell Manuf 22(3):367–378
57. Zhang R, Song S, Wu C (2012) A two-stage hybrid particle swarm optimization algorithm for the stochastic job shop scheduling problem. Knowl Based Syst 27:393–406
58. Zhang W, Gen M, Jo JB (2014) Hybrid sam-pling strategy-based multiobjective evolutionary algorithm for process planning and scheduling problem. J Intell Manuf 25(5):881–897
59. Zhang WQ, Xu WT et al (2015) An effective hybrid evolutionary algorithm for stochastic multiobjective assembly line balancing problem. J Intell Manuf. p 8. doi:10.1007/s10845-015-1037-5
60. Zhou R, Nee AYC, Lee HP (2009) Performance of an ant colony optimisation algorithm in dynamic jobshop scheduling problems. Int J Prod Res 47:2903–2920
61. Zitzler E, Thiele L (1999) Multiobjective evolutionary algorithms: a comparative case study and the strength Pareto approach. IEEE Trans Evol Comput 3(4):257–271
62. Zitzler E, Laumanns M, Thiele L (2001) SPEA2: Improving the strength pareto evolutionary algorithm, Technical Report 103, Computer Engineering and Communication Networks Lab (TIK)

Chapter 89
Advances in Hybrid Metaheuristics for Stochastic Manufacturing Scheduling: Part II Case Studies

Mitsuo Gen, Wenqiang Zhang and Xinchang Hao

Abstract Manufacturing Scheduling plays a very important role in the intelligent manufacturing system, where it can have a major impact on the productivity of a production process. However, it is very difficult to find an optimal solution for manufacturing scheduling problems since most of them fall into the class of NP-hard problem. Because real world manufacturing problems often contain nonlinearities, multiple objectives conflicting each other and also uncertainties that are too complex to be modeled analytically. In these environments, hybrid metaheuristic based optimization is a powerful tool to find optimal system settings to the stochastic manufacturing scheduling problems. Evolutionary algorithm (EA) in hybrid metaheuristics is a generic population-based metaheuristic, which can find compromised optimal solutions well for a complicated manufacturing scheduling problem. By using the hybrid sampling strategy-based EA (HSS-EA) and the multi-objective estimation of distribution algorithm (MoEDA), we survey several case studies such as stochastic multi-objective jobshop scheduling problem (S-MoJSP), stochastic multi-objective assembly line balancing (S-MoALB) problem and stochastic multi-objective resource-constrained project scheduling problem (S-MoRcPSP) with numerical experimental results to get the better efficacy and efficiency than existing NSGA-II, SPEA2 and awGA algorithms.

Keywords Multi-objective evolutionary algorithms (MoEAs) · Multi-objective estimation of distribution algorithm (MoEDA) · Stochastic jobshop scheduling problem (S-JSP) · Stochastic assembly line balancing (S-ALB) · Stochastic resource-constrained project scheduling problem (S-RcPSP)

M. Gen (✉)
Fuzzy Logic Systems Institute, Tokyo University of Science, Tokyo, Japan
e-mail: gen@flsi.or.jp

W. Zhang
College of Information Science and Engineering, Henan University of Technology, Hunan, People's Republic of China

X. Hao
Graduate School of Information, Production and Systems, Waseda University, Tokyo, Japan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_89

89.1 Introduction

In real world manufacturing systems there are many combinatorial optimization problems (COP) imposing on more complex issues, such as complex structure, non-linear constraints, and multiple objectives to be handled simultaneously. Manufacturing scheduling is one of the important and complex COP models, where it can have a major impact on the productivity of a production process. Moreover, the COP models make the problem intractable to the traditional optimization techniques because most of scheduling problems fall into the class of NP-hard combinatorial problems [10, 12]. In order to develop effective and efficient solution algorithms that are in a sense good, i.e., whose computational time is small as within 3 min, or at least reasonable for NP-hard combinatorial problems met in practice, we have to consider: Quality of solution, Computational time and Effectiveness of the non-dominated solutions for a multi-objective optimization problem (MOP) consisting of multiple and conflicting objectives [11].

They surveyed multi-objective hybrid genetic algorithms (MoHGA) for manufacturing scheduling problems and applied to real world problems for the hard disc device (HDD) and the thin-film transistor-liquid crystal display (TFF-LCD) manufacturing systems, respectively [11]. Recently Gutjahr and Pichler [15] surveyed a stochastic MOP (S-MOP) methods based on non-scaling for risk-neutral decision makers. The stochastic model has been observed in a large range of application fields such as finance, energy, transportation logistics, facility location, manufacturing and production planning, supply chain management, humanitarian logistics, telecommunication, health care management or project management [15]. The S-MOP models arise in the design, modeling, and planning of many real complex manufacturing systems in particular in the areas of the multi-objective jobshop scheduling problems (MoJSP), the multi-objective assembly line balancing (MoALB) problems and the multi-objective resource-constrained project scheduling problems (MoRcPSP).

The paper is organized as follows: Sect. 89.2 introduces practical stochastic models such as stochastic multi-objective JSP (S-MoJSP) model and the computational experiment results. Section 89.3 introduces stochastic multiobjective ALB (S-MoALB) model and the computational experiment results. Section 89.4 introduces stochastic multiobjective multimode RcPAP (S-MmRcPSP) model and the numerical experiment results. In Sect. 89.5 the conclusion and future work are given.

89.2 Stochastic Multiobjective Jobshop Scheduling Models

89.2.1 Stochastic BJSP Model

The jobshop scheduling problem (JSP) is one basic model of manufacturing scheduling problems and very popular in manufacturing systems. As one famous combinatorial optimization problems known as NP-hard [7, 22], generally JSP aims at minimizing the makespan with the considering of precedence and resource constraints. The uncertainty in JSP models may stem from a number of possible sources: operation may take more or less time than originally estimated, resources may become unavailable, due dates may have to be changed, or new orders may have to be incorporated, etc. [21]. Gu et al. [14] proposed a novel parallel quantum genetic algorithm for solving the stochastic JSP with the objective of minimizing the expected value. Lei [23] proposed Pareto archive particle swarm optimization for solving multiobjective fuzzy job shop scheduling problems and also reported efficient genetic algorithm (GA) to minimize makespan for scheduling stochastic job shop with random breakdown and applied to some test problems and compared with a simulated annealing (SA) and a PSO in which the computational results showed the GA performs better than PSO and SA for stochastic JSPs [24]. Hao et al. proposed effective estimation of distribution algorithm (EDA) for solving stochastic JSP [17], Markov network based EDA for solving flexible jobshop scheduling problems (FJSP) under uncertainty [18] and effective multiobjective EDA for solving stochastic bicriteria jobshop scheduling problem (S-BoJSP) [19].

In order to solve a jobshop scheduling problem in stochastic and static environments, the probability distribution of the processing time is assumed to be known in advance. The realized outcome of a random processing time of operation only gets to be known at the completion of the processing. The stochastic jobshop scheduling problem (S-JSP) can be formulated as an extended version of JSP. The stochastic expected value model of stochastic bicriteria jobshop scheduling problem (S-BoJSP) may be formulated as follows: The makespan is the maximum completion time of jobs and objective is to find a schedule that minimizes the expected value of makespan Cmax, the equation Eq. (89.1) and the expected total tardiness, the equation Eq. (89.2) conflicting each other.

Indices:
i,k: index of jobs; $i, k = 1, \dots, J$;
j, h: index of operations; $j, h = 1, \dots, N$;
m: index of machines; $m = 1, \dots, M$

Parameters:
J: number of jobs;
N: number of operations;
M: number of machines;
o_{ij}: operation j of the job i;
C_i: completion-time of the job i;
d_i: due-date of the job i;
p^{ξ}_{ijm}: random processing time of operation o_{ij} under scenario ξ;
L_i: $\max\{0, C_i - d_i\}$, the tardiness of job i;
w_i: tardiness level (weight) of the job i;
$\mathcal{N}$: a positive big number enough as a penalty factor

Decision Variables:

x_{ikm}: 1, if job i precedes job k on machine m; 0, otherwise;

y_{ijm}: 1, if it is available to process operation o_{ij} on machine m; 0, otherwise;

s^{ξ}_{ijm}: starting time operation o_{ij} on machine m, a stochastic variable;

c^{ξ}_{ijm}: completion time operation o_{ij} on machine m, a stochastic variable

The stochastic bi-criteria jobshop scheduling problem (S-BoJSP) can be formulated as a nonlinear mixed integer programming model as follows:

$$\min \ \mathrm{E}[C_{\max}] = \mathrm{E}[\max_{i=1,\ldots,J}\{\max_{j=1,\ldots,N}\{\max_{m=1,\ldots,M} c^{\xi}_{ijm}\}\}] \tag{89.1}$$

$$\min \ \mathrm{E}[T_{\mathrm{tot}}] = \sum\nolimits_{i=1}^{J} w_i \mathrm{E}[\max\{0, L_i\}] \tag{89.2}$$

$$\text{s. t.} \ \sum_{m=1}^{M} y_{ijm} \le 1, \quad \forall i, j \tag{89.3}$$

$$\sum_{m=1}^{M} x_{ikm} y_{ijm} = 1, \quad \forall i, j, k \tag{89.4}$$

$$\mathrm{E}\left[\sum_{m=1}^{M} s^{\xi}_{ijm} + p^{\xi}_{ij} y_{ijm}\right] \le \mathrm{E}\left[\sum_{m=1}^{M} \xi s_{i(j+1)m}\right], \quad \forall i, j \tag{89.5}$$

$$\mathrm{E}\left[\sum_{i=1}^{J}\sum_{j=1}^{N}(s^{\xi}_{ijm} + p^{\xi}_{ij} y_{ijm})\right] \le \mathrm{E}\left[\sum_{i=1}^{J}\sum_{k=1}^{J}\sum_{h=1}^{N}(s^{\xi}_{khm} x_{ikm} + N(1 - x_{ikm}))\right], \quad \forall m \tag{89.6}$$

$$c^{\xi}_{khm} \ge 0, s^{\xi}_{khm} \ge 0, x_{ikm}, y_{ijm} \in [0, 1] \forall i, j, k, h, m, \tag{89.7}$$

where, the Eq. (89.3) shows that only one operation can be in each sequence on a machine. The Eq. (89.4) guarantees that each operation for each job must be allocated to just one machine in a sequence. The Eq. (89.5) guarantees the operation precedence sequences for each job. The Eq. (89.6) shows that each operation's processing time does not have any overlap with any other Eq. (89.7) represents the nonnegative restrictions.

89.2.2 *Experiments of S-BJSP Model by MoEDA*

In order to ensure the fairness of comparison, three large-scale instances LA29 (10×20), LA35 (30×10) and LA38 (15×15) of proposed in Lawrence (1984) are adopted in this paper, where due dates and the tightness level of the due dates are designed according to the design policy of Essafi, Mati and Dauzére-Pèrés [4]. According to practical observation for which 20 % of customers are very important, 60 % are of average importance and the remaining 20 % are of less importance, 20 % of jobs are assigned a weight of 4, 60 % of jobs are assigned a weight of 2 and weight of 1 sets to the remainder of jobs. For the processing time uncertainty, the processing time of operation o_{ij} may equally take any real value from the uniform distribution where

Table 89.1 The Parameters of NSGA-II, SPEA2, awGA and h-moEDA for S-JSP

	NSGA-II, SPEA2 and awGA	moEDA
Iteration	1000	1000
Population	200	200
Selection	Roulette	Tournament (k)
Operators	Crossover (P_c)	Sampling
	Mutation (P_m)	Improvement (P_i)
Parameters	$P_m = 0.20$	Promising Rate = 0.7
	$P_c = 0.80$	$\alpha = 0.02$, $\beta = 0.02$
	$\omega_1 = 0.4$, $\omega_2 = 0.6$	$P_m = 0.4$, $k = 2$

and are the given lower and upper bounds respectively. The expected processing time of an operation is to be equal to the processing time of that operation in original instances. The upper and lower processing time bounds of an operation affected by uniform variation in its processing time is calculated by:

$$[\underline{t}_{ij}, \bar{t}_{ij}] = t_{ij}^{E} \times [1, (1+\gamma)]. \tag{89.8}$$

The 30 % of operations is under uncertainty and disturbance ratio is assigned to 0.3. For measuring the uncertainty, a set of 400 scenarios Ξ is sampled as the input of S-JSP. The due date of the job depend on the expected processing times of its operations, Data were collated from 30 test runs for each algorithm. In order to compare the performance of these algorithms fairly and under the same environment, the strategies of related algorithms and their respective parameters are presented in Table 89.1.

In order to evaluate the performance of a given algorithm for S-JSP, the following two performance measures are considered in this paper. Let S_j be a solution set for each solution method ($j = 1, 2, 3, 4$). S^* is a known set of the Pareto-optimal set.

Coverage $C(S_1, S_2)$ is the percent of the chromosomes in S_2 who are weakly dominated by S_1. The value $C(S_1, S_2) = 1$ means that all chromosomes in S_2 are weakly dominated by S_1. On the contrary, $C(S_1, S_2) = 0$ denotes that none of the chromosomes in S_2 is weakly dominated by S_1 [32]. The larger $C(S1, S2)$ is; the better $S1$ outperforms S_2 in C.

Spacing SP (S_j) is the standard deviation of the closest distances of chromosomes by S_j. Smaller SP means better distribution performance. The C is used to verify convergence performance while SP is used to check the distribution performance.

Table 89.2 and Fig. 89.1 present the distribution range of coverage conducted on LA35. From Table 89.2 and Fig. 89.1, it is easy to see that the hybrid-MoEDA is better than MSGA-II, SPEA2and awGA on C measure.

Such better convergence should mainly attribute to the hybrid sampling strategy of VEGA's preference for the edge region of the Pareto front and PDDR-FF's tendency converging toward the center area of the Pareto front. They preserve better performances both in efficacy and efficiency. Especially, hybrid-MoEDA can also

Table 89.2 Comparison of coverage measure by h-moEDA, awGA, NSGA-II and SPEA2

Problem algorithm (A)		Mean			Standard deviation	
		C(h-mpEDA, A)	C(A, h-mpEDA)	Improves C(A, h-mpEDA) -C(A, h-mpEDA)) (%)	(C(h-mpEDA, A)	C(h-mpEDA, A)
LA29	NSGA-II	0.4669	0.3524	11.45	0.0842	0.0709
	SPEA2	0.4965	0.3224	17.41	0.0696	0.0603
	awGA	0.5731	0.2541	31.90	0.0451	0.0553
LA35	NSGA-II	0.6486	0.2824	36.63	0.0777	0.0794
	SPEA2	0.6606	0.2618	39.89	0.0860	0.0631
	awGA	0.6844	0.2171	46.73	0.0672	0.0460
LA38	NSGA-II	0.4543	0.3425	11.19	0.0799	0.0754
	SPEA2	0.5063	0.3412	16.52	0.0696	0.0603
	awGA	0.5625	0.2767	28.58	0.0572	0.0619

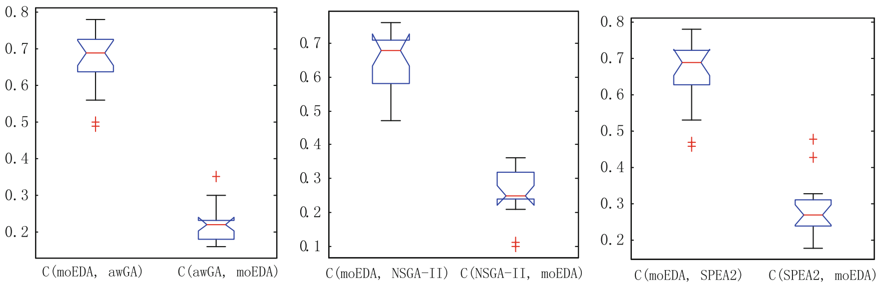
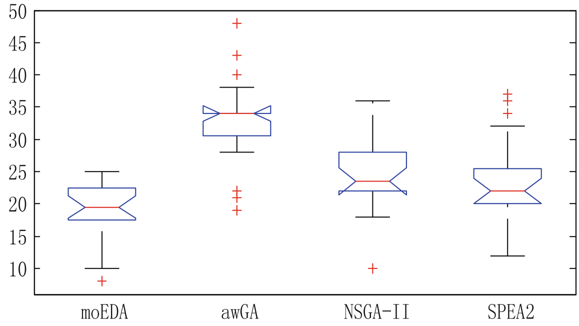


Fig. 89.1 Box plot of coverage measure conducted on LA35

Fig. 89.2 Box plot of space measure conducted on LA35



keep diversity evenly without special distribution mechanisms like NSGA-II and SPEA2. For the experiment results of dispersion performances, Fig. 89.2 presents the distribution range of space conducted on LA35. It indicates that MoEDA is obviously better than awGA, while better than NSGA-II and SPEA2. Without special mechanism to preserve the diversity evenly, hybrid-MoEDA can also achieve satisfactory dispersion performance.

89.3 Stochastic Multi-objective Assembly Line Balancing Model

89.3.1 Stochastic BoALB Model

The assembly line balancing (ALB) problem concerns the assignment of the tasks into stations to minimize the cycle time and processing cost under the constraint of precedence relationships. It is one of very important modern manufacturing systems to produce mass products [9, 27]. Recently several stochastic assembly line balancing (S-ALB) models and methods reported on single objective and multi-objective optimization. Fazlollahtabar et al. [5] proposed a model based on the rank positional weight algorithm by considering stochastic activity task times; two other methodologies of normal distribution integration and Monte Carlo simulation were developed. Nazarian and Ko [25] proposed a new method and model for a robust line design to overcome inefficient and unsystematic determination of the buffer time, which was based on cycle time violation and manufacturing time variations. Hazñr and Dolgui [20] presented two robust optimization models with interval and operation uncertainty at each station. They proposed a decomposition-based algorithm combined with enhancement strategies to optimally solve large-scale instances of assembly line problems. The above works mostly focus on single objective optimization. For multi-objective optimization in uncertain environments, Cakir et al. [1] developed a hybrid-simulated annealing algorithm. They used multinomial probability mass functions, repair algorithms, and diversification strategies to deal with the single-model S-ALB problem with parallel stations. Hamta and Ghomi [16] produced a bi-criteria nonlinear integer programming model to combine two inconsistent objective functions, and incorporated a genetic algorithm to handle ALB with flexible task times. Although single-objective, stochastic, assembly-line balancing problems have been investigated by various researchers, there remains a lack of optimization methodology for multi-objective stochastic problems.

Recently Zhang et al. [29] reported multi-objective evolutionary algorithm with strong convergence of multi-area for solving ALB problem with worker capability, Zhang et al. [30] proposed hybrid sampling strategy-based evolutionary algorithm (HSS-EA) for solving the process planning and scheduling problem and Zhang et al. [31] proposed an effective HSS-EA for solving stochastic multiobjective assembly line balancing (S-MoALB) problem. Difference to the conventional ALB, the duration of processing time may take any real value from the uniform distribution $U(\underline{t}_j, \bar{t}_j)$ where $\underline{t}_j$ and $\bar{t}_j$ are the given lower and upper bounds respectively. Therefore, the duration uncertainty can be constructed through the concept scenario ξ which corresponds to an assignment of reasonable duration on task j. This finite set of scenarios Ξ is sampled as input of S-BoALB which the processing time satisfies the intervals $[\underline{t}_j, \bar{t}_j]$.

The S-BoALB model concerns with the assignment of the tasks (each task $j = 1, 2, \ldots, n$ with processing time t_j^{ξ} and processing cost d_j^{ξ} under the scenario ξ) to stations (each station $i = 1, 2, \ldots, m$) for each station in order to minimize the cycle time and minimize the processing cost under the constraint of precedence relationships. The Suc(j) is the set of direct successors of task j and Pre(j) is the set of direct predecessors of task j. S_i^{ξ} is the set of tasks assigned to station i under the scenario ξ. $t(S_i^{\xi}) = \sum_{j=1}^{n} t_j^{\xi} x_{ij} \forall i$ is the processing time at station i under the scenario ξ. The decision variable $x_{ij} = 1$ means if the task j is assigned to station i, otherwise, $x_{ij} = 0$. Therefore, the mathematical model of S-BoALB can be formulated as follows:

$$\min\ \mathrm{E}[c_T^{\xi}] = \mathrm{E}\left[\max_{1\le i\le m}\left\{\sum\nolimits_{j=1}^{n}\sum\nolimits_{w=1}^{m} t_j^{\xi} x_{ij}\right\}\right], \tag{89.9}$$

$$\min\ \mathrm{E}[d_T^{\xi}] = \mathrm{E}\left[\sum\nolimits_{i=1}^{m}\sum\nolimits_{j\in S_i} d_j^{\xi}\right], \tag{89.10}$$

$$\text{s. t.}\ \sum\nolimits_{i=1}^{m} i x_{ij} \ge \sum\nolimits_{i=1}^{m} i x_{ik},\quad \forall k \in \mathrm{Pre}(j),\quad \forall j, \tag{89.11}$$

$$\sum\nolimits_{i=1}^{m} x_{ij} = 1,\quad \forall j, \tag{89.12}$$

$$x_{ij} \in \{0, 1\},\quad \forall i, j. \tag{89.13}$$

The first objective Eq. (89.9) of the model is to minimize the expectation of the cycle time of the assembly line. The second objective Eq. (89.10) is to minimize the expectation of the total processing cost. Inequity (89.11) states that all predecessor of task j must be assign to a station, which is in front of or the same as the station that task j is assigned in Eq. (89.12) ensures that task j must be assigned to only one station. Equation (89.13) represents the nonnegative restrictions.

89.3.2 Experiments of S-BoALB Model by HSS-EA

For solving the stochastic biobjective assembly line balancing (S-BoALB) prob-lem by HSS-EA, we employed Gunther's problem data with 35 tasks and 6 stations, which is widely used in the ALB problem literature in Scholl [26]. For the duration uncertainty, the expected duration t_j^E is to be equal to duration of that task in original instances. The upper and lower processing time bounds of a task affected by uniform variation in its duration is calculated by:

$$[\underline{t}_j, \bar{t}_j] = t_j^E \times [1, (1+\gamma)]. \tag{89.14}$$

In this paper a linear function is considered between the cost and the processing time. Therefore, the problem is to make a balance between the costs and the processing time as two incomparable objectives. The processing cost of each task is calculated by:

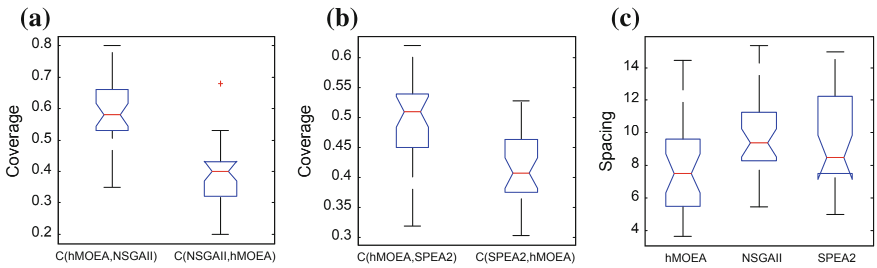


Fig. 89.3 Coverage C and Spacing SP by three methods: hMoEA, NSGA-II and SPEA2

$$d_j^{\xi} = \max_{1 \le j \le n} \left\{ t_j^{\xi} + 1 - t_j^{\xi} \right\}. \tag{89.15}$$

If 30 % of operations is under uncertainty, the disturbance ratio will be assigned to 0.3. For measuring the uncertainty, a set of 150 scenarios Ξ is sampled as the input of S-BoALB.

The adopted parameters are listed as follows: population size, 200; maximum generation, 1000; archive size, 100; crossover probability, 0.80 and 0.3; mutation probability, 0.40 and 0.1. hMoEA, NSGA-II, and SPEA2 are run 30 times to compared the results with each other. It should be noted that the parameters of all 3 methods are the same, except for the size of archive. The archive sizes of h-MoEA is set to be half the population size, 100, while of NSGA-II and SPEA2 are set to be the same as the population size, 200. Let S_j be a solution set for each method. PF^* is a known reference Pareto solutions. In this study, PF^* in this study comes from combining all of the obtained Pareto set (combining all the scenarios) with 30 runs by 3 methods. The following two performance measures are considered.

Coverage $C(S_1, S_2)$ is the percent of the individuals in S_2 which are weakly dominated by S_1. The larger $C(S_1, S_2)$ means that S_1 outperforms S_2 in convergence.

Spacing SP (S_j) is the standard deviation of the closest distances of individuals by S_j. Smaller SP means better distribution performance.

The $C(S_1, S_2)$ is used to verify convergence performance while SP (S_j) is used to check the distribution performance.

Figure 89.3 shows the numerical comparison of the box-and-whisker plots for $C(S_1, S_2)$ and SP (S_j) by 3 methods. Fig. 89.3a and b demonstrate that the hMoEA is better than other two methods on $C(S_1, S_2)$ measure. The distribution performance SP (S_j) indicates that hMoEA is slightly better than NSGA-II and SPEA2 methods as shown in Fig. 89.3c. In general, the convergence and distribution performance of hMoEA is better than traditional famous NSGA-II and SPEA2.

89.4 Stochastic Multi-mode Resource-Constrained Project Scheduling Model

89.4.1 Stochastic MmRcPSP Model

Project scheduling is a complex process involving many resource types and activities that require optimizing. The requirement of resource type may often influence the requirement of other types. The resource-constrained project scheduling problem (RcPSP) is a well-known problem where activities of a project must be scheduled to minimize the project duration, i.e., makespan [9]. The RcPSP is a generalization of the static jobshop scheduling, flowshop scheduling, assembly line balancing, related scheduling problems and hence belongs to the class of NP hard problems [9]. When there are several different modes in RCPSP model that may be selected for an activity, the problem is known as a resource-constrained project scheduling problem with multiple modes (MmRcPSP). In this paper, we consider the stochastic multi-mode resource constrained project scheduling problem (S-MoRcPSP) where each activity $j, j = 1, \ldots, N$ has to be executed in one of $M_j, j = 1, \ldots, N$. It is assumed that the activities are non-preemptable and decision on the mode of activity is not changeable until the activity is completed (without preemption).

Difference to the conventional PSP, the duration of activity j on mode m may equally take any real value from the uniform distribution where $\underline{d}_{jm}$ and $\bar{d}_{jm}$ are the given lower and upper bounds respectively. Therefore, the duration uncertainty can be constructed through the concept scenario which corresponds to an assignment of reasonable duration on activity j. We present a slack-based version programming model to transmute the duration in term of stochastic variables. It assumes that the probability distribution of the duration of activity is known in advance. Therefore, S-MmRcPSP can be defined the decision making process as follows:

Mode assignment (m-selection): determine the mode of activity that can be similarly processed on one of the multiple mode candidates.

Activities sequencing (seq): determine the sequence for executing all activities so that the precedence relationships among all of the activities are not violated.

Robust scheduling: measuring robustness of a decision solution m-selection and seq which is relatively insensitive quality to the duration uncertainty.

For measuring the robustness of the given solution (m-selection, seq), a finite set of scenarios Ξ is sampled as input of S-MmRcPSP from a set of the Cartesian product of the internals $[\underline{d}_{jm}, \bar{d}_{jm}], j = 1, \ldots, N, m = 1, \ldots, M_j$. The multi-objective mathematical programming model of S-MmRcPSP minimizing the expected makespan and maximizing slack-based robustness that considers the effect of the immediate successors and resource requirements of activity j simultaneously may be formulated as follows:

Indices:
i, j: index of activities, $i, j = 1, \ldots, N$
m: index of modes of activity j, $m = 1, \ldots, M_j$
k: index of renewable resources, k, $k = 1, \ldots, K$
Ξ: scenario which corresponds to an assignment of reasonable duration on activity, $\xi \in \Xi$

Parameters:
N: number of activities
M_j: number of modes of activity j, $j = 1, \ldots, N$
K: number of renewable resources
N_k: number of available units of renewable resource k, $k = 1, \ldots, K$
d_{im}^{ξ}: duration of activity j performed in mode m under the scenario ξ, $j = 1, \ldots, N$, $\xi \in \Xi$
r_{jkm}: amount of the resource k occupied by the activity j in mode m
p_j: set of all predecessors of activity j
A_j: set of available modes for activity j
$nSuc_j$: number of immediate successor s of activity j
s_j: amount of time that an activity j can slip without delaying the start of any of its immediate successors while upholding resource feasibility

Decision variable:
x_{jmt}: 1, if activity j is performed in mode m at time t; 0, otherwise
s_{jm}^{ξ}: starting time of activity j under the scenario ξ, $\xi \in \Xi$
c_{jm}^{ξ}: completion time of activity j under the scenario ξ, $\xi \in \Xi$

Mathematical Model:

$$\min \ \mathrm{E}[C_{\max}] = \mathrm{E}\left[\frac{\sum_{\xi \not\in} \max_{\mathrm{j}=1,\ldots,\mathrm{N}} \mathrm{c}_{\mathrm{j}}^{\xi}}{|\Xi|}\right] \tag{89.16}$$

$$\max \ \mathrm{E}[R_M] = \mathrm{E}\left[\sum\nolimits_{j=1}^{N} \sum\nolimits_{k=1}^{K} r_{jk} nSuc_j s_j^{\xi}\right] \tag{89.17}$$

$$\text{s. t. } \mathrm{E}\left[\sum\nolimits_{i=1}^{M_i} \sum\nolimits_{t=s_i^{\xi}}^{c_i^{\xi}} t x_{imt}\right] \le \mathrm{E}\left[\sum\nolimits_{j=1}^{M_j} \sum\nolimits_{t'=s_i^{\xi}}^{c_i^{\xi}} (t' - d_{jm}) x_{jmt'}\right], j = 1, \ldots, N; i \in p_j; \xi \in \Xi \tag{89.18}$$

$$\mathrm{E}\left[\sum_{m=1}^{M_j} \sum_{t=s_j^{\xi}}^{c_j^{\xi}} x_{jmt}\right] = 1, \quad j = 1, \ldots, N; \xi \in \Xi \tag{89.19}$$

$$\mathrm{E}\left[\sum_{j=1}^{N} \sum_{m=1}^{M_j} r_{jkm} \sum_{b=t}^{t+d_{jm}^{\xi}-1} x_{jmt}\right] \le N_k, \quad j = 1, \ldots, N; \ k = 1, \ldots, K; \ \xi \in \Xi; \ t = 1, \ldots, \text{ horizon} \tag{89.20}$$

$$x_{jmt} \in \{0, 1\}, j = 1, \ldots, N; m = 1 \cdots M_j; \ t = 1 \cdots \text{horizon} \tag{89.21}$$

$$s_j^{\xi} \ge 0, c_j^{\xi} \ge 0, \quad j = 1, \ldots, N; \quad \xi \in \Xi \tag{89.22}$$

Inequality (89.18) describes the precedence constraints of activity. Equation (89.19) states that one mode must be selected from a set of available modes for each activity. Inequality (89.20) takes into account the constraint on the limitation of renewable resource. Equations (89.21) and (89.22) represent the nonnegative restrictions.

89.4.2 Experiments of S-MoRcPSP by MoEDA

To examine the practical viability and efficiency of the multi-objective estimation of distribution algorithm (MoEDA) to solve the stochastic multi-mode resource constrained project scheduling problem (S-RcPSP), we designed a numerical study to compare the MoEDA with efficient algorithms from previous studies. The proposed moEDA was compared with adaptive weight Genetic Algorithm (awGA) proposed by Gen and Cheng [7] from hybrid GA, adaptive GA and random-key based GA approaches, non-dominated sorting genetic algorithm II (NSGA-II) by Deb et al. [2, 3] and strength Pareto evolutionary algorithm 2 (SPEA2) by Zitzler et al. [33].

Mode sampling: Once the structure of the MNm-selection has been estimated, the model selection of new candidate solution will be sampled from the estimated model. Unlike to Bayesian network, most of the MNs do not satisfy the ancestral ordering of variables needed for probabilistic logic sampling. An extended Gibbs sampler, a class of the Markov Chain Monte Carlo method, is selected as the sampling method in our algorithm. For this study, the linear schedule is used for representing the temperature function: $T \sim 1/\text{gen}^{*}\beta$, where β is the cooling rate parameter and is the given number of generations (iterations) reached. For establishing the trade-off between exploration and exploitation, the value of β is set to 0.5.

Robustness assessing: For measuring the robustness of solution s(x, seq) that consists of machine assignment x and operations sequence seq under the processing time uncertainty, the slack-based metric is used to assess the robustness under the input X_j Firstly, a predictive schedule is generated according to decision values s under each scenario $\xi \in \Xi$. Thereafter, critical path-based algorithm proposed in research work [1], is used to improve the robustness by searching through the solution space.

Fitness Assignment Mechanisms: Many multi-objective Genetic Algorithms differ mainly in the fitness assignment strategy which is known as an important issue in solving multiple objectives optimization problem [9]. Zhang et al. [30] proposed a hybrid sampling strategy-based evolutionary algorithm (HSS-EA) in which a Pareto dominating and dominated relationship-based fitness function (PDDR-FF) is used to evaluate the individuals.

In this numerical experiment, the one large-scale instance $j30$ of 30 activities x 3 modes in psplib are adopted. According to practical observation for which 20 % of activities are very important, 60 % are of average importance and the remaining 20 % are of less importance, 20 % of activities are assigned a weight of 4, 60 % of activities are assigned a weight of 2 and weight of 1 sets to the remainder of activities.

For the duration uncertainty, the expected duration d_{jm}^{E} is to be equal to duration of that activity in original instances. The upper and lower processing time bounds of an activity affected by uniform variation in its duration is calculated as $[\underline{d}_{jm}, \bar{d}_{jm}] =$

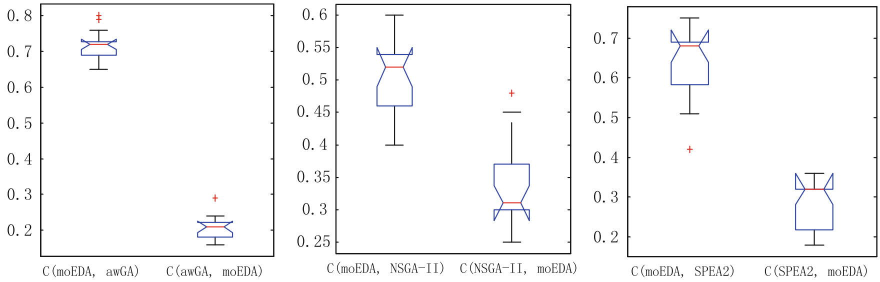


Fig. 89.4 Comparison of coverage measure by by moEDA, awGA, NSGA-II, and SPEA2

Table 89.3 Comparison of the spacing (mean and standard deviation) about MoEDA, NSGA-II, SPEA2 and awGA

Mean		Reduced	Standard deviation	
SP(MoEDA)	SP(NSGA-II)	(SP(MoEDA)-SP(NSGA-II))/SP(NSGA-II)	SP(MoEDA)	SP(NSGA-II)
17.9448	20.9786	−14.46 %	3.2167	4.3435
SP(MoEDA)	SP(SPEA2)	(SP(MoEDA)-SP(SPEA2))/SP(SPEA2)	SP(MoEDA)	SP(SPEA2)
17.9448	24.646	−27.19 %	3.2167	7.3646
SP(MoEDA)	SP(awGA)	(SP(MoEDA)-SP(awGA))/SP(awGA)	SP(MoEDA)	SP(awGA)
17.9448	32.9452	−45.53 %	3.2167	8.1396

$d^E_{jm} \times [1, (1+\gamma)]$, and 30 % of operations is under uncertainty and disturbance ratio is assigned to 0.3. For measuring the uncertainty, a set of 300 scenarios is sampled as the input of S-MoRcPSP. Furthermore, the population is 200 and iteration of generation is 1000.

In order to evaluate the performance of a given algorithm for S-MoRcPSP, the following two performance measures are considered. Let S_j be a solution set for each solution method ($j = 1, 2, 3, 4$). S^* is a known set of the Pareto-optimal set 1). Coverage $C(S_1, S_2)$ is the percent of the individuals in S_2 who are weakly dominated by S_1. The value $C(S_1, S_2) = 1$ means that all individuals in S_2 are weakly dominated by S_1. On the contrary, $C(S_1, S_2) = 0$ denotes that none of individuals in S_2 is weakly dominated by S_1. The larger $C(S_1, S_2)$ is, the better S_1 outperforms S_2 in C. 2) Spacing SP (S_j)is the standard deviation of the closest distances of individuals by S_j. Smaller SP means better distribution performance. The C is used to verify convergence performance while SP is used to check the distribution performance. Fig. 89.4 show the comparison of coverage by MoEDA, awGA, NSGA-II and SPEA2. It is easy to see that the MoEDA is better than NSGA-II, SPEA2 and awGA on C measure. The experiment results of dispersion performances, SP are shown in Table 89.3. It indicates that MoEDA is obviously better than awGA (46 % reduced), while better than NSGA-II and SPEA2.

(about 14 and 27 %). Without special mechanism to preserve the diversity evenly, MoEDA can also achieve satisfactory dispersion performance

89.5 Conclusions

Scheduling in real world plays a very important role in the integrated manufacturing system, where it can have a major impact on the productivity of a production process. However, it is very difficult to find an optimal solution for manufacturing scheduling problems since most of them fall into the class of NP-hard problem. Because real world manufacturing problems often contain nonlinearities, multiple objectives conflicting each other and also uncertainties that are too complex to be modeled analytically. In these environmental situation, hybrid metaheuristics based optimization technique is a powerful tool to find optimal system settings to the stochastic manufacturing scheduling problems. Evolutionary algorithm (EA) in hybrid metaheuristics is a generic population-based metaheuristic algorithm, which can find a best compromised optimal solutions among a lot of Pareto optimal solutions to multi-objective optimization problems (MOPs) well for a complicated nonlinear scheduling problem with multiple objectives conflicting each other.

This paper demonstrated recent hybrid metaheuristics for solving stochastic multi-objective jobshop scheduling (S-MoJSP), stochastic multi-objective assembly line balancing (S-MoALB) and stochastic multi-objective multi-mode resource-constrained project scheduling (S-MmRcPSP) problems by experimental results to get the better efficacy and efficiency than existing multi-objective evolutionary algorithms (MoEAs). Future work is to expand stochastic scheduling by hybrid metaheuristics to real world manufacturing problems.

Acknowledgments This work is partly supported by the Grant-in-Aid for Scientific Research (C) of Japan Society of Promotion of Science (JSPS): No. 15K00357, National Science Foundation of China: No.61572100, Fundamental Research Funds for the Central Universities No. DUT15QY10, National Natural Science Foundation of China: No. U1304609, the Key Young Teacher Training Program of Henan University of Technology, the Fundamental Research Funds for the Henan Provincial Colleges and Universities No. 2014YWQQ12, and Research Funds for Key Laboratory of Grain Information Processing and Control (Henan University of Technology), Ministry of Education, China.

References

1. Cakir B, Altiparmak F, Dengiz B (2011) Multi-objective optimization of a stochastic assembly line balancing: a hybrid simulated annealing algorithm. Comput Ind Eng 60(3):376–384
2. Deb K (2001) Multi-objective optimization using evolutionary algorithms, vol 16. Wiley, New York
3. Deb K, Pratap A et al (2002) A fast and elitist multiobjective genetic algorithm: Nsga-ii. IEEE Trans Evol Comput 6(2):182–197

4. Essafi I, Mati Y et al (2008) A genetic local search algorithm for minimizing total weighted tardiness in the job-shop scheduling problem. Comput Oper Res 35(8):2599–2616
5. Fazlollahtabar H, Hajmohammadi H, Es'haghzadeh A (2011) A heuristic methodology for assembly line balancing considering stochastic time and validity testing. Int J Adv Manuf Technol 52(1–4):311–320
6. Gao J, Gen M, Sun L (2006) Scheduling jobs and maintenances in flexible job shop with a hybrid genetic algorithm. J Intell Manuf 17(4):493–507
7. Gen M, Cheng R (2000) Genetic algorithms and engineering optimization. Wiley, New York
8. Gen M, Lin L (2014) Multiobjective evolutionary algorithm for manufacturing scheduling problems: state-of-the-art survey. J Intell Manuf 25(5):849–866
9. Gen M, Cheng R, Lin L (2008) Network models and optimization: multiobjective genetic algorithm approach. Springer, Berlin
10. Gen M, Lin L, Zhang W (2015) Multiobjective hybrid genetic algorithms for manufacturing scheduling: Part I models and algorithms. In: Proceedings of the ninth international conference on management science and engineering management, Springer, Berlin, pp 3–25
11. Gen M, Lin L, Zhang WQ, Y Yun (2015) Recent hybrid metaheuristics for multiobjective scheduling. In: Proceedings of the international conference on computers & industrial engineering, p 12
12. Gen M, Zhang W, Lin L (2015) Multiobjective hybrid genetic algorithms for manufacturing scheduling: part II case studies of hdd and tft-lcd. In: Proceedings of the ninth international conference on management science and engineering management, Springer, Berlin, pp 27–54
13. Gen M, Hao X, Zhang W (2016) Advances in hybrid metaheuristics for stochastic manufacturing scheduling: Part I models and methods. In: Proceedings of The 10th international conference on management science and engineering management
14. Gu J, Gu X, Gu M (2009) A novel parallel quantum genetic algorithm for stochastic job shop scheduling. J Math Anal Appl 355(1):63–81
15. Gutjahr WJ, Pichler A (2013) Stochastic multi-objective optimization: a survey on non-scalarizing methods. Ann Oper Res 236:475–499
16. Hamta N, Ghomi SF et al (2011) Bi-criteria assembly line balancing by considering flexible operation times. Appl Math Model 35(12):5592–5608
17. Hao X, Lin L et al (2013) Effective estimation of distribution algorithm for stochastic job shop scheduling problem. Procedia Comput Sci 20:102–107
18. Hao X, Lin L et al (2014) An effective markov network based eda for flexible job shop scheduling problems under uncertainty. In: Proceedings of the IEEE international conference on automation science and engineering (CASE), pp 131–136
19. Hao X, Gen M et al (2015) Effective multiobjective eda for bi-criteria stochastic job-shop scheduling problem. J Intell Manuf pp 1–13
20. Hazır Ö, Dolgui A (2013) Assembly line balancing under uncertainty: robust optimization models and exact solution method. Comput Ind Eng 65(2):261–267
21. Herroelen W, Leus R (2005) Project scheduling under uncertainty: Survey and research potentials. Eur J Oper Res 165(2):289–306
22. Lawrence S (1984) Resource constrained project scheduling: an experimental investigation of heuristic scheduling techniques (supplement). Master's thesis, Carnegie-Mellon University, Pittsburgh, PA
23. Lei D (2008) Pareto archive particle swarm optimization for multi-objective fuzzy job shop scheduling problems. Int J Adv Manuf Technol 37(1–2):157–165
24. Lei Dm (2012) Minimizing makespan for scheduling stochastic job shop with random breakdown. Appl Math Comput 218(24):11851–11858
25. Nazarian E, Ko J (2013) Robust manufacturing line design with controlled moderate robustness in bottleneck buffer time to manage stochastic inter-task times. J Manuf Syst 32(2):382–391
26. Scholl A (1993) Data of assembly line balancing problems. Schriften zur quantitativen Betriebswirtschaftslehre
27. Zhang W, Gen M (2011) An efficient multiobjective genetic algorithm for mixed-model assembly line balancing problem considering demand ratio-based cycle time. J Intell Manuf 22(3):367–378

28. Zhang W, Gen M, Lin L (2008) A multiobjective genetic algorithm for assembly line balancing problem with worker allocation. In: IEEE international conference on proceedings of the systems, man and cybernetics, SMC 2008, IEEE, pp 3026–3033
29. Zhang W, Xu W, Gen M (2013) Multi-objective evolutionary algorithm with strong convergence of multi-area for assembly line balancing problem with worker capability. Procedia Comput Sci 20:83–89
30. Zhang W, Gen M, Jo J (2014) Hybrid sampling strategy-based multiobjective evolutionary algorithm for process planning and scheduling problem. J Intell Manuf 25(5):881–897
31. Zhang W, Xu W et al (2015) An effective hybrid evolutionary algorithm for stochastic multiobjective assembly line balancing problem. J Intell Manuf, pp 1–8
32. Zitzler E, Thiele L (1999) Multiobjective evolutionary algorithms: a comparative case study and the strength pareto approach. IEEE Trans Evol Comput, 3(4):257–271
33. Zitzler E, Laumanns M et al (2001) SPEA2: Improving the Strength Pareto Evolutionary Algorithm, Technical Report 103. Comp. Eng. and Com, Networks Lab (TIK)

Chapter 90
A Feasibility Analysis of Three Numerical Schemes for the Prediction of Two Phase Transient Flow

Min Luo, Yong Zhang, Jiancheng Hu, Shize Wang, Bin Qi and Zhiguo Qiao

Abstract This paper presents a coupled system model of partial differential equations concerning the variation of pressure and temperature, velocity and density at different time and depth of two-phase flow wells in HTHP statement. LxF, CE/SE and GRP method are modified to solve this set of conservation equations. The basic data of 'X Well' (HTHP well), 7100 m deep, located in Sichuan basin, South-west of China, is used for the case history calculations. The comparison of pressures and temperatures calculated by those methods shows that the model is efficient and GRP method is of highest accuracy, which will be an important technical reliance for the process of designing well tests in HTHP wells.

Keywords Prediction · HTHP · CE/SE · LxF · GRP

M. Luo
Guanghua School of Management, Peking University, Beijing 100871,
People's Republic of China

M. Luo
Mathematics Department, Chengdu University of Information Technology,
Chengdu 610225,
People's Republic of China

M. Luo
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610064,
People's Republic of China

Y. Zhang (✉)
School of Mathematical Sciences, Beijing Normal University, Beijing 100875, China
e-mail: zhangyong@bnu.edu.cn

J. Hu · S. Wang · B. Qi · Z. Qiao
Research School of Engineering Technology, China Petroleum and Chemical Corp,
Deyang 618000, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_90

90.1 Introduction

Transient gas-liquid flow in a wellbore is always characterized by the dependence of pressure, liquid holdup, gas and liquid density, velocity, and other related flow parameters on both time and space. As for pressure research of two-phase flow, there exist empirical formulas, such as those given by Beggs, Mukherjee, etc. Beggs and Brill method works in horizontal, vertical and inclined flow. It also takes into account the different horizontal flow regimes. The method uses the general mechanical energy balance and the average in-situ density to calculate the pressure gradient in [1]. Mukherjee studied the pressure drop behavior in two-phase inclined flow and presented a friction factor correlation for pressure gradient of annular-mist flow in [9]. Different researchers such as Hurlburt and Candia have proposed mechanistic models in [2, 4], assuming that flow is under steady-state conditions, while other researchers such as Ouyang have proposed unsteady-state gas-liquid two-phase flow models in [10]. However, such models only predict the pressure profiles but not the temperature profiles and their interdependence is ignored. Wu et al. have presented a coupled system model of differential equations in [11] concerning pressure and temperature in HTHP wells, but this model only considers the steady statement.

In this paper, we consider the transient statement and build a simulation model with a set of coupled partial differential equations of pressure, temperature, density and velocity in HTHP gas-liquid two-phase flow wells on both time and space. Gas-liquid flow in inclined pipes was investigated to determine the effect of the pipe inclination angle on liquid holdup. Correlations for liquid and friction factors were considered in the prediction for two-phase flow in pipes of all angles for annular flow in this model. The well-bore temperature calculation considers the heat-transmission within wellbore and from wellbore to formation as transient, and the pressure calculation considers the influence of friction resistance and dynamic energy variation. Finally, we set up equations according to the laws of mass balance, momentum balance and energy balance. The equations set up in the model constructed a hyperbolic system of conservation law.

Scientists have developed a lot of high-accuracy methods to solve the conservation law these years. Godunov established classical Godunov scheme in [3] for the computation of discontinuous solution of conservation law of the fluid dynamics. Lax developed Lax–Friedrichs method [6] as an alternative to Godunov's scheme, where one avoids solving a Riemann problem at each cell interface, at the expense of adding artificial viscosity. Researchers have developed many successful difference schemes with what can effectively suppress the unphysical oscillations of discontinuity. In recent years, some new algorithms have emerged to pursuit of high precision and high resolution of discontinuities, for example, CE/SE [14] and GRP [7]. Each method has its own characteristics, and they can provide effective tools for computational fluid dynamics.

Space-Time Conservation Element and Solution Element (CE/SE) method set up by Chang has many merits such as the clear physics concept, high accuracy and the simple process of constructing the scheme. Mathematically, the conservation laws of two-phase flow are represented by a set of integral equations. For a physical solution in a region of rapid change, the smoothness assumption is difficult to be realized by normal numerical approximation. As for CE/SE method, space and time are unified and treated as a single entity, both local and global flux conservation in space and time are enforced and a multidimensional scheme is constructed without using the dimensional-splitting approach, so that multidimensional effects and source terms can be modeled more realistically.

Generalized Riemann Problem (GRP) scheme, which is an analytic extension of the Godunov scheme. Riemann invariants are applied to resolve the singularity at the jump discontinuity, where each local wave pattern always fixes with speed zero, rarefaction and shock waves locates on either side. Because the extension of the scheme to multidimensional cases is obtained using splitting technology, to get the integration in time of the conservation laws becomes more simple and direct.

To enable efficient engineering calculations, we developed solution procedures based on Lax–Friedrichs method [7], CE/SE method [8] and GRP method [7], for the approximate modeling of two-phase flow well. The basic data of the model for the calculation are from X well, 7100 m of depth in Sichuan Basin, Southwest of China. Through comparing the results calculated by these three methods we found that GRP method got more accurate predictions of pressure and temperature compared with those obtained from LxF method and CE/SE method. GRP method has great efficiency in the computer calculation process and the results can provide a technical reliance for the process of designing well tests in HTHP gas-liquid wells and a dynamic analysis of production from wells.

90.2 Model Formulation

In Fig. 90.1, the mixture density and velocity are related to the in-situ liquid volume fraction (holdup), H, as follows:

$$\begin{cases} \rho_m = \rho_l H + \rho_g(1-H), \\ v_m = v_l H + v_g(1-H). \end{cases} \tag{90.1}$$

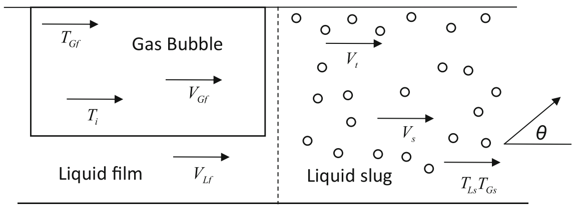


Fig. 90.1 The two phase flow

90.2.1 Mass Balance

Considering the flow model and according to the fundamental physical principle [5], for the fluid moves through the fixed control volume, we obtain the mass balance equation

$$\frac{\partial \rho_m}{\partial t} + \frac{\partial(\rho_m \nu_m)}{\partial z} = 0. \tag{90.2}$$

90.2.2 Momentum Balance

For a transient flow system, the integral form of the z component of the momentum equation can be written as below with the external forces, and we can finally obtain the momentum balance equation

$$\frac{\partial}{\partial t}(\rho_m V_m) + \frac{\partial}{\partial z}(P + \rho V^2) = -\rho_m g \cos\theta - \frac{\lambda \rho_m \nu^2}{2d}. \tag{90.3}$$

90.2.3 Energy Balance

For the transient flow, it directly leads to a form of the energy equation in terms of temperature. We should consider the heat-transmission within wellbore or from wellbore to formation as transient. According to the energy balance law, we get the energy balance equation of transient flow

$$\frac{\partial(\rho_m \nu_m T)}{\partial z} + \frac{\partial(\rho_m T)}{\partial t} = 2\pi K_e r_{t0} U_{t0}(T_{ei} - T)/C_P(K_e + r_{t0} U_{t0} T_{wbD}). \tag{90.4}$$

In addition, the stated equation of gas is as below:

$$\rho_m = MP\gamma_g/ZRT. \tag{90.5}$$

Finally, we obtain the coupled system model of partial differential equations about the gas density, velocity, temperature and pressure with initial condition:

$$\begin{cases} \partial\rho_m/\partial t + \partial(\rho_m \nu_m)/\partial z = 0 \\ \partial(\rho_m \nu_m)/\partial t + \partial(P + \rho_m \nu_m^2)/\partial z = -\rho_m g \cos\theta - \lambda/2d \\ \partial(\rho_m T)/\partial t + \partial(\rho_m \nu_m T)/\partial z = 2\pi K_e r_{t0} U_{t0}(T_{ei} - T)/C_P(K_e + r_{t0} U_{t0} T_{wbD}) \\ \rho_m = MP\gamma_g/ZRT \\ (P, T, \rho_m, \nu_m) = (P_0, T_0, \rho_{m0}, \nu_{m0}) \quad t = 0, \quad z = 0. \end{cases} \tag{90.6}$$

90.3 Format Construction of Solving Model

90.3.1 LxF Method

We unify the conservation Eqs. (90.2), (90.3) and (90.4) into the following formula:

$$\frac{\partial A_m}{\partial t} + \frac{\partial B_m}{\partial z} = C_m, \qquad m = 1, 2, 3. \tag{90.7}$$

When $m = 1, 2, 3$, there be

$$\begin{cases} A_1 = \rho \\ B_1 = G \\ C_1 = 0 \end{cases}, \begin{cases} A_2 = G \\ B_2 = P + G^2/\rho \\ C_2 = (-\rho g\cos\theta - \lambda G\,|G|)/2\rho d \end{cases}, \tag{90.8}$$
$$\begin{cases} A_3 = \rho T_e \\ B_3 = G T_e \\ C_3 = 2\pi K_e r_{t0} U_{t0}(T_{ei} - T_e)/C_P(K_e + r_{t0}U_{t0}T_{wbD}) \end{cases}.$$

We use Lax–Friedrichs scheme to discretize the conservation Eq. (90.8). In particular, we discretize part on the right side of the equation with central difference format. Then, we obtain the following deference forms of Eq. (90.8):

$$\frac{(A_m)_j^{n+1} - 1/2[(A_m)_{j-1}^n + (A_m)_{j+1}^n]}{\tau} + \frac{(B_m)_{j+1}^n - (B_m)_{j-1}^n}{2h} \tag{90.9}$$
$$= \frac{(C_m)_{j+1}^{n+1}}{2} + \frac{(C_m)_j^{n+1}}{2}.$$

We transform (90.12) as below:

$$\frac{\Delta A_m}{\tau} + \frac{\Delta B_m}{2h} = \frac{\Delta C_m}{2}, \quad m = 1, 2, 3. \tag{90.10}$$

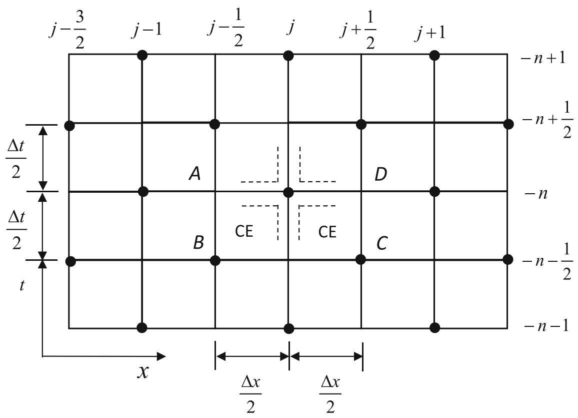
90.3.2 CE/SE Method

We discretize the definite region by using finite discrete grid as Fig. 90.2 shows and we can get the following differential form of the integral conservation law:

$$\oint_{S(V)} \overrightarrow{h_m} \cdot d\,\overrightarrow{S} = \oint_V \overrightarrow{C_m} \cdot d\,\overrightarrow{V}. \tag{90.11}$$

We divide the computational domain into conservation elements as Fig. 90.2 shows. Assume solution elements are approached by first-order Taylor expansions,

Fig. 90.2 Grid for CE/SE scheme



thus

$$
\begin{aligned}
A_m{}^*(z,t;\,j,n) &= (A_m)_j^n + (A_{mz})_j^n(z-z_j) + (A_{mt})_j^n(t-t^n),\\
B_m{}^*(z,t;\,j,n) &= (B_m)_j^n + (B_{mz})_j^n(z-z_j) + (B_{mt})_j^n(t-t^n).
\end{aligned} \tag{90.12}
$$

Then, we define potential function as follows:

$$
\begin{aligned}
&\partial\varphi_m/\partial t = A_m{}^*(z,t;\,j,n),\quad \partial\varphi_m/\partial z = -B_m{}^*(z,t;\,j,n),\\
&\varphi_m(z,t;\,j,n) = (A_{mt})_j^n(t-t^n) - (B_{mz})_j^n(z-z_j) + 1/2(A_{mt})_j^n(t-t^n)^2\\
&+[(A_{mz})_j^n - (B_{mt})_j^n](t-t^n)(z-z_j) - 1/2(B_{mz})_j^n(z-z_j)^2.
\end{aligned} \tag{90.13}
$$

Combine Eqs. (90.12) and (90.13) into (90.11), we obtain the space-time scheme

$$
\begin{aligned}
&(A_m)_j^n - (C_m)_j^n\Delta t/4 = 1/2\Big\{(A_m)_{j-1/2}^{n-1/2} + (A_m)_{j+1/2}^{n-1/2}\\
&+ (C_m)_{j-1/2}^{n-1/2} + (C_m)_{j+1/2}^{n-1/2}\Delta t/4 + (S_m)_{j-1/2}^{n-1/2} - (S_m)_{j-1/2}^{n-1/2}\Big\}\\
&(S_m)_j^n = \Delta z/4(A_{mz})_j^n + \Delta t/\Delta z\Big[(B_m)_j^n + \Delta t/4(B_{mt})_j^n\Big].
\end{aligned} \tag{90.14}
$$

90.3.3 GRP Method

We define the equally-spaced grid points, the interface points and the cells as $z_j = j\Delta z$, $z_{j+1/2} = (z_j + z_{j+1})/2$, $C_j = [z_{j-1/2}, z_{j+1/2}]$.

Assume that the data at time $t = t_n$ are piecewise linear with a slope σ_j^n, we have $U(z,t_n) = U_j^n + \sigma_j^n(z-z_j)$, $z \in (z_{j-1/2}, z_{j+1/2})$.

The second order Godunov scheme for (90.6) has the following form: $U_j^{n+1} = U_j^n - \frac{\Delta t}{\Delta x}(F(U_{j+1/2}^{n+1/2}) - F(U_{j-1/2}^{n+1/2}))$, and $U_{j+1/2}^{n+1/2}$ is the mid-point value or the value of U at the cell interface $(z_{j+1/2}, t_n)$ which has accuracy of second order. More specifically, the mid-point value $U_{j+1/2}^{n+1/2}$ is computed with the formula $U_{j+1/2}^{n+1} = U_{j+1/2}^{n} + \frac{\Delta t}{2}(\frac{\partial U}{\partial t})_{j+1/2}^{n}$ and $U_{j+1/2}^{n} = R^A(0; U_{j+1/2,-}^{n}, U_{j+1/2,+}^{n})$.

$R^A\left((z - z_{j+1/2})/(t - t_n); U_{j+1/2,-}^{n}, U_{j+1/2,+}^{n}\right)$ is the solution of the Riemann problem centered at $(z_{j+1/2}, t_n)$. $U_{j+1/2,-}^{n}$ and $U_{j+1/2,+}^{n}$ are the limiting values of initial data $U(z, t_n)$ on both sides of $(z_{j+1/2}, t_n)$.

The initial structure of the solution is determined by the associated Riemann solution, denoted as $\lim_{t\to 0} U(\lambda t, t) = R^A(\lambda; U_L, U_R)$, $\lambda = x/t$.

90.4 Numerical Analysis

In this simulation, we study a pipe in *X* well locating in Sichuan basin, Southwest of China. All the needed parameters are given as following: Internal fluid density is 1000 kg/m^3; External fluid density is 1000 kg/m^3; Depth of the well is 7100 m; Friction coefficient is 1.2; Ground temperature is 160 °C; Ground thermal conductivity parameter is 2.06; Ground temperature gradient is 0.0218 °C/m; Length of one segment is 1 m. The mixed initial temperature is 74.20 °C, pressure is 41.23 MPa, density is 269.32 kg/m^3 and velocity is 5.50 m/s.

Parameters of pipes are given in Table 90.1. Inclination, azimuth and vertical depth are given in Table 90.2. Through the algorithm and simulation, we can obtain series of results contained in tables and figures and analyze these results as below.

When the bottom pressure is 70 MPa, we use three different methods to calculate out the temperatures at different depth. The results of the detail are shown in Table 90.3. When the output keeps constant, the temperature increases with the increasing depth of the well; and when the depth fixed, the temperature increases with the increasing time. In addition, it can be seen from the figure that the temperature changes quickly in the early stage but stabilizes over time.

As shown in Table 90.5, for the comparative results of well head temperature at 1200 s, the relative error between the calculation results and the measurement results of LxF method is 4.99 %, by CE/SE method is 3.42 %, while the relative error between the results calculated by GRP method is 2.61 %, which shows that the temperature

Table 90.1 Parameters of pipes

Diameter	Thickness	Weight	Expansion	Coefficient	Young	Modulus
88.9	9.53	18.9	0.0000115	215	0.3	1400
88.9	7.34	15.18	0.0000115	215	0.3	750
88.9	6.45	13.69	0.0000115	215	0.3	4200
73	7.82	12.8	0.0000115	215	0.3	600
73	5.51	9.52	0.0000115	215	0.3	150

Table 90.2 Parameters of azimuth, inclination and vertical depth

Number	Measured	Inclination	Azimuth	Vertical depth	Number	Measured	Inclination	Azimuth	Vertical depth
1	0	0	120.33	0	13	3605	2.05	123.25	3603.36
2	303	1.97	121.2	302.87	14	3901	0.16	121.45	3899.22
3	600	1.93	120.28	599.73	15	4183	2.92	121.24	4181.09
4	899	0.75	126.57	898.59	16	4492	2.73	129.22	4489.95
5	1206	1.25	124.9	1205.45	17	4816.07	1.98	121.61	4813.87
6	1505	1.04	124.62	1504.32	18	5099.07	2.74	129.93	5096.74
7	1800	0.49	123.75	1799.18	19	5394.07	0.13	120.46	5391.61
8	2105	2.49	125.27	2104.04	20	5706.07	0.63	129.59	5703.47
9	2401	1.27	123.13	2399.91	21	5983.07	2.09	120.14	5980.34
10	2669	2.44	120.12	2667.79	22	6302.07	2.69	122.91	6299.19
11	3021	0.14	127.39	3019.63	23	6597.07	2.45	129.41	6594.06
12	3299	1.18	122.6	3297.5	24	6911.12	0.15	124.88	6907.96

Table 90.3 Temperature at different depth of different methods on 1200 s

Metnod depth	LxF	CE/SE	GRP	Metnod depth	LxF	CE/SE	GRP
0	124.28	126.16	125.19	3600	156.45	156.98	156.46
300	128.35	128.74	127.34	3900	158.58	159.95	158.74
600	131.26	132.62	131.67	4200	160.34	161.72	160.38
900	134.28	135.94	134.88	4500	161.72	162.53	161.55
1200	137.45	138.72	137.43	4800	162.56	163.42	162.62
1500	140.57	141.57	140.65	5100	163.57	164.34	163.55
1800	143.12	143.13	142.31	5400	164.88	165.23	164.9
2100	146.21	146.17	145.78	5700	165.59	165.94	165.33
2400	148.36	149.67	148.53	6000	167.43	168.2	167.78
2700	150.57	151.67	150.66	6300	168.91	170.15	168.97
3000	152.73	153.93	152.39	6600	169.86	172.31	169.65
3300	154.88	155.86	154.79	6900	170.48	173.37	171.89

distribution prediction of the two-phase flow by GRP method is more accurate in actual calculation than the other two methods.

It is established that when depth is constant, the pressure at 1200 s calculated by three methods are shown in Table 90.4 and increased with the increasing of the time. When the output keeps constant, the pressure increases with the increasing depth of the well. This is because with time increasing, the flow increases and then the frictional heat leads to an increase of the pressure. It can also be seen that the pressure changes quickly in the early stage but stabilizes over time. In Table 90.5, for the comparative results of well head pressure at 1200 s, the relative error between

Table 90.4 Pressure at different depth of different methods on 1200 s

Method depth	LxF	CE/SE	GRP	Metnod depth	LxF	CE/SE	GRP
0	43.85	47.51	49.03	3600	56.65	59.97	58.98
300	44.12	47.89	50.45	3900	57.43	60.99	59.13
600	45.86	48.45	50.76	4200	58.65	61.23	60.45
900	46.97	49.63	51.46	4500	59.45	62.76	61.76
1200	47.43	50.76	52.32	4800	60.76	63.87	62.45
1500	48.75	51.54	53.46	5100	61.98	64.34	63.34
1800	49.56	52.43	54.55	5400	63.43	65.56	64.29
2100	50.45	53.76	55.57	5700	64.78	65.67	65.31
2400	51.86	54.89	55.76	6000	65.98	66.89	66.27
2700	53.34	57.43	55.84	6300	66.42	67.55	67.23
3000	54.56	58.56	56.53	6600	67.55	68.78	68.43
3300	55.43	59.88	57.56	6900	69.76	69.57	69.98

Table 90.5 Comparative results of well head at 1200 s

Well-bottom	Temperature	Pressure
Measurement results	128.55	48.52
Results by LxF (relative error)	124.28 (4.99 %)	43.85 (12.36 %)
Results by CE/SE (relative error)	126.16 (3.42 %)	47.51 (3.92 %)
Results by GRP (relative error)	129.33 (2.61 %)	49.03 (3.54 %)

the calculation results and the measurement results by LxF method is 12.36 %, while the relative error between the results calculated by CE/SE method is 3.92 %, by GRP method is 3.54 %, which also proves that the model by GRP method is more accurate in pressure distribution prediction.

90.5 Conclusion

In this paper, we present a system model of partial differential equations according to mass, momentum and energy, considering the variation of pressure, temperature, velocity and density by different time and depth in gas-liquid two-phase flow. We establish an algorithm model with a new different method with LxF (Lax–Friedrichs) method, CE/SE (Space-Time Conservation Element and Solution Element) method and GRP (Generalized Riemann Problem) scheme which are proved to be efficient for the numerical implementation in this paper. The basic data of the X Well (HTHP well), with a depth of 7100 m in Sichuan basin, Southwest of China, was used for case history calculations, and a sensitivity analysis is completed for the model. The result shows that the temperature distribution prediction of the two-phase flow by GRP method is more accurate in actual calculation than the other two methods. It can provide the technical reliance of more accurate and more efficient calculation method for the process of designing well tests and dynamic analysis of production. Furthermore, the work in this paper can raise safety and reliability of deep completion test, and avoid or lessen accidents caused by improper technical designs.

Acknowledgments This project was supported by National Natural Science Foundation of China (11501035, 70831005) and the Key Project of China Petroleum and Chemical Corporation (GJ-73-0706).

References

1. Beggs DH, Brill JP et al (1973) A study of two-phase flow in inclined pipes. J Pet Technol 25(05):607–617
2. Cazarez-Candia O, Vásquez-Cruz MA (2005) Prediction of pressure, temperature, and velocity distribution of two-phase flow in oil wells. J Pet Sci Eng 46(3):195–208
3. Godunov S (1959) A finite difference method for the numerical computation and discontinuous solutioins of the equations of fluid dynamics. Matematicheskii Sbornik 47:21–28
4. Hurlburt E, Hanratty T (2002) Prediction of the transition from stratified to slug and plug flow for long pipes. Int J Multiph Flow 28(5):707–729
5. John D, Anderson JR, Anderson (2002). Computational fluid dynamics -The basics with applications, Mc Graw-Hill, USA
6. Lax PD (1973) Hyperbolic systems of conservation laws and the mathematical theory of shock waves, vol 11. SIAM
7. Li J, Chen G (2006) The generalized riemann problem method for the shallow water equations with bottom topography. Int J Numer Methods Eng 65(6):834–862
8. Luo M, Hu J (2013) CE/SE method for solving a class of hyperbolic systems of conservation laws. J Sichuan Univ 50(4):97–110 (in Chinese)
9. Mukherjee H, Brill JP et al (1983) Liquid holdup correlations for inclined two-phase flow. J Pet Technol 35(05):1–003
10. Ouyang LB, Aziz K (2001) Transient gas-liquid two-phase flow in pipes with radial influx or efflux. J Pet Sci Eng 30(3):167–179
11. Wu Z, Xu J et al (2011) Predicting temperature and pressure in high-temperature-high-pressure gas wells. Pet Sci Technol 29(2):132–148
12. Xu J, Luo M et al (2013) A direct eulerian grp scheme for the prediction of gas-liquid two-phase flow in hthp transient wells. In: Abstract and Applied Analysis, vol 2013, Hindawi Publishing Corporation, Cairo
13. Xu J, Luo M et al (2013) Pressure and temperature prediction of transient flow in hthp injection wells by lax-friedrichs method. Pet Sci Technol 31(9):960–976
14. Zhang ZC, Yu SJ, Chang SC (2002) A space-time conservation element and solution element method for solving the two-and three-dimensional unsteady euler equations using quadrilateral and hexahedral meshes. J Comput Phys 175(1):168–199

Chapter 91
Gaming of Green Supply Chain Members Under Government Subsidies—Based on the Perspective of Demand Uncertainty

Hua Zhuo and Song Wei

Abstract With the rapid development of global economy, the demand of natural resources is increasing rapidly, and the depletion of natural resources and environmental protection are becoming more and more serious. The implementation of the green supply chain management can achieve the win-win situation of economic and environmental benefits, truly enhance the core competitiveness of enterprises and promote economic sustainable development, which becomes the important direction of the implementation of national sustainable development strategy. Aiming at the characteristics of uncertainty demands in consumer market, Based on the government subsidy function and Stackelberg model, the paper constructs a three level green supply chain system which including manufacturers, suppliers and customers, and analyzes the incentive mechanism on the decision-making and profit of the supply chain members. With the help of Matlab 7.0, the arousal effect of government subsidies and the lower limit of greenness are analyzed. The results show that: by increasing the intensity and access threshold of subsidies, the government can stimulate the demands of consumer market and reduce the adverse effects to the manufacturers and suppliers because of the risk of demand uncertainty.

Keywords Green supply chains · Government subsidies · Gaming models · Demand uncertainty

91.1 Introduction

With the rapid development of the world economy, the traditional manufacturing business have created a lot of material wealth for human beings, but the resources shortage, greenhouse effect and other environmental problems caused by it can not be ignored. How to maximize the utilization of resources and reduce the negative impact on the environment has become an increasingly important issue for scholars

H. Zhuo (✉) · S. Wei
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 1310067367@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_91

and governments at home and abroad. In order to alleviate pressures caused by various economic activities, the relevant laws and regulations have been established by every country to bring environmental protection into the daily management and strategic decision of enterprises. But the efforts of individual enterprises can not effectively improve the conflict between enterprises and the environment in whole market, and the green supply chain management is a new management mode to solve this problem. The concept of green supply chain was first proposed by the research group "Environmentally responsible manufacturing" in manufacturing Research Institute of Michigan State University in 1996 [7], combined with the relevant literature, this paper defines the green supply chain as: throughout environmental protection awareness into the entire product life cycle process, which contains product design, manufacturing, packaging, transportation, use and disposal, and finally consult out green products through the green design, green materials, green packaging, green recycling and other technical means, so all enterprises in supply chain can achieve mutual profits and make the least negative impact on the environment [9]. As a super manufacturing country, resource waste and environmental destruction events occur frequently in China, so improving the green supply chain management is particularly important. To promote enterprises carrying out the green supply chain work, Chinese government developed a series of incentives, such as the energy-saving products project jointly promoted by the national development and Reform Commission, Ministry of industry, Ministry of Finance in 2009, giving financial subsidies to air conditioners, refrigerators, washing machines and other ten types of energy-saving products which efficiency standard over one or two level. In order t offset the rising cost of R&D and production of energy-saving products. Because of the strong support of the government, the supply chain will develop in the direction of the green supply chain, and the members of the supply chain will carry out game in the green supply chain management. In order to study the situation, that is, the strategic choice of the green supply chain members when the demand is uncertain, this paper builds a Stackelberg game model, which is used to study the decision-making problem of the manufacturers and sellers in the green supply chain.

91.2 Literature Review

In recent years, domestic and foreign scholars' research on the green supply chain management mainly has the following several aspects: (1) The relationship between green supply chain management and enterprise performance. Using the questionnaire, Ye [10] built the structural equation model to analyze the relationship between product green design and enterprise performance. Results showed that the external competitors and policies regulations have a significant positive impact on the green design. Green design can significantly increase the environmental performance and economic performance. Using grey correlation evaluation method, Yi [2] conducted transverse and longitudinal analysis to green supply chain management performance of four steel enterprises. The results showed that, from 2005 to 2010, green supply chain management level of the four steel enterprises raise gradually. Mirhedayatian [6] also studied on the economic performance and environmental performance of the green supply chain by using the DEA model under the pressure of the relevant policies regulations. (2) Driving factors analysis of green supply chain management. Su [8] used confirmatory factor analysis method to investigate the main factors affecting green technology cooperation between enterprises in supply chain, results showed that the characteristics of enterprise green technology, the external environmental pressure, dependencies between upstream and downstream enterprises of supply chain all have a greater effect to green technology cooperation, which are basically the same with most of the existing research results. (3) Comparison analysis of the traditional supply chain and the green supply chain. Jin [4] set up a game model composed of ordinary products and green products, and analyzed the model optimal equilibrium solution in a variety of situations, gained the optimal decision-making of enterprise and the government's optimal incentive policy. (4) Research on the relationships of main parts in green supply chain. Li [5] conducted evolutionary game model and analyzed the enterprises' emission reduction behavior under government supervision. The model pointed out that government can choose to supervise or not, enterprises can choose whether to implement the green supply chain, given the costs and benefits of the enterprises' low carbon production, government supervision and taxation, and obtained the evolutionary stable strategy of different situations. Considering the underpowered problem of current enterprises' green cooperation, Zuo [12] researched the relationship between cluster supply chain green cooperative behavior and government regulation. Results showed that: the waste's production scale, waste re-use fixed investment, raw materials procurement prices are prerequisite to cluster supply chain green cooperation; government's fines to waste discharge, government's regulatory costs, government's reputation loss incurred by supervision dereliction all have a varying degrees impact on cluster supply chain green cooperation. From the standpoint of stochastic output, Zeng [11] studied the incentive mechanism of government subsidies to green supply chain system composed by manufacturer and retailer, through the mathematical method, and analyzed the stochastic output factors' influence to supply chain members' decision and profit. Jiang [3] established four green supply chain game model: Stackelberg game model dominated by manufacturer, Stackelberg game model dominated by seller, Nash equilibrium game model and centralized control model. Jiang [3] carried out the comparative analysis to four kinds of game models in terms of product green degree, product price and wholesale price, and established the game model under revenue sharing contract.

According to the documents, it is found that research on the influence of product greenness on supply chain members' decision making is relatively less while considering the demand uncertainty and government subsidies at the same time. So under the premise of an uncertainty demand on green products, this paper builds a game model of green supply chain consisting of manufacturers, sellers and consumers. So we can provide theoretical support for manufacturers and retailers in green supply chain management.

91.3 Model Description and Assumption

To promote a class of green products, expand consumer demand, improve energy efficiency and promote industrial upgrading, the government invested a certain amount of funds, considering to give subsidies to the products whose greenness are more than g_0, we called the floor level of greenness, the government subsidy coefficient for per product is r, and the consumer demand q is an uncertain function. To produce green products manufacturers need to assume a certain additional cost, that is, unit marginal cost will increased by λ on the basic of the initial ordinary product cost c, but also need to pay a certain R&D costs I. Because the market demand is uncertain, so we assumed the expected value of actual sales volume is s. At the same time considered surplus products' residual value h. In this paper, we consider the three-level of green supply chain composed of a single manufacturer, retailer and customer, in which the manufacturer is in the dominant position, and the government offer subsidies to manufacturers according to the greenness of the product. Supply chain decision-making process is as follows: after subsidy policy to green products is issued by government, manufacturers will first make decisions about product greenness g_m and product wholesale price in order to achieve the maximization target interests, in the observation to the manufacturer's decision, sellers will determine green product's ordering quantity. Specific variables are described as follows:

p : Seller's unit product price;
w : Seller's unit product cost, that is, the manufacturer's unit wholesale price;
h : Surplus products' residual value, $p > w > h$;
q : Consumer demand, which is a function of the uniform distribution between 0 and a, $q \sim [0, a]$;
$f(x)$: The probability density functions of consumer demand, $f(x) = 1/a$;
$F(x)$: The probability distribution function of consumer demand, $F(x) = x/a$, $x \in [0, a]$;
y : The products number that seller actually ordered from the manufacturer;
g_m : The product's greenness level, this paper believes that the green degree level is continuous;
c : Unit marginal cost of the manufacturer's ordinary products, there are $w > c$;
g_0 : Minimum subsidy level of greenness, $g_m > g_0$;
I : Manufacturer's R&D costs;
λ : Assume there is a linear correlation between increased unit cost and greenness, The product cost coefficient $\lambda = \varepsilon(g_m - g_0)$;
t : unit product's subsidy coefficient adjustment factor;
r : Government subsidy coefficient to per unit of sales products, $r = t(g_m - g_0)$;
π_1 : Manufacturer's profit function;
π_2 : seller's profit function;
S : Expected value of actual sales volume when seller's ordering quantity is y, $S = \int_0^y xf(x)dx + \int_y^\infty yf(x)dx = y - \int_0^y F(x)dx$

There is a dynamic multi game between green supply chain members, under the condition of not changing the problem nature, the model do the following assumptions:

Hypothesis 1: government subsidy program has been determined, that is, subsidy coefficient to per unit of sales products and the level of greenness have been determined;

Hypothesis 2: game process only considers the problems between manufacturer and distributor, sellers and consumers. It is considered that the manufacturers, sellers and consumers are limited rational economic men, and aimed at maximizing their self-interest;

Hypothesis 3: customers have no preference for the greenness of the product, only influenced by the product price and market capacity;

Hypothesis 4: referencing the classic A-J model in Technology Management, which considered there exists quadratic relation between R&D results and R&D investment [1]. So in this paper, we think there exists quadratic relation between manufacturer's fixed cost and greenness level: $I = \beta(g_m)^2$.

Called β is the fixed investment cost coefficient and assumed that the value of β can guarantee the existence of the equilibrium solution of the game.

Based on the above assumptions, we obtain that:

Manufacturer's profit function:

$$\pi_1 = (w - c - \lambda + wr)\, y - 1. \tag{91.1}$$

Seller's profit function:

$$\pi_2 = ps + h\,(y - s) - wy. \tag{91.2}$$

91.4 The Game Model of Green Supply Chain Under the Government Subsidy

In the green supply chain management, considering the uncertainty of demand, product greenness, government subsidies and other factors, the paper establishes a Stackelberg game model of manufacturers and retailers: the first stage, manufacturer develops production strategy according to the government's subsidy policy, and determines product's greenness g and product's wholesale price w; second stage, seller determines the order strategy and product order quantity y according to the manufacturer's decision-making and market demand information. The following model is solved by using backward induction method.

First, we should analyze seller's decision behavior, by substituting actual sales of green products into the formula (91.2); we get the formula (91.3):

Seller's profit function:

$$\pi_2 = (p - w)y - (p - h)\int_0^y F(x)dx. \tag{91.3}$$

Take partial derivative of π_2 with respect to y, we can get:

$$\begin{cases} \frac{\partial \pi_2}{\partial y} = p - w - (p - h)F(y), \\ \frac{\partial^2 \pi_2}{\partial y^2} = -(p - h)f(y). \end{cases} \tag{91.4}$$

Because the product price is greater than the residual value, so $\frac{\partial^2 \pi_2}{\partial y^2} < 0$, formula (91.4) is a decreasing function, we can get:

$$\begin{cases} \frac{\partial \pi_2}{\partial y}{}_{y=0} = p - w - (p - h)F(0) = p - w > 0, \\ \frac{\partial \pi_2}{\partial y}{}_{y=\infty} = p - w - (p - h)F(\infty) = h - w < 0. \end{cases} \tag{91.5}$$

So there is bound to be an order quantity that makes formula equal to zero, and at this time the sales profit is the maximum value. Based on this, we can get the formula (91.6):

$$y^* = F^{-1}\left(\frac{p - w}{p - h}\right). \tag{91.6}$$

Secondly, we should analyze manufacturer's decision-making behavior. By substituting obtained y^* into formula (91.1), and due to the assumption of market demand is a uniform distribution function between 0 and a, so the probability density function of consumer demand $f(x) = 1/a$ and the probability distribution function of consumer demand $F(x) = x/a$, then manufacturer's profit function π_1 becomes formula we get the formula (91.7):

$$\begin{aligned} \pi_1 &= (w - c - \varepsilon(g_m - g_0) + wt(g_m - g_0))F^{-1}(\frac{p - w}{p - h}) - \beta(g_m)^2 \\ &= (w - c - \varepsilon(g_m - g_0) + wt(g_m - g_0))\frac{a(p - w)}{p - h} - \beta(g_m)^2. \end{aligned} \tag{91.7}$$

Take first order partial derivative of pi_1 with respect to w and g, we can get formula (91.8):

$$\begin{cases} \dfrac{\partial \pi_1}{\partial \omega} = \dfrac{a(p - w)(1 + t(g_m - g_0))}{p - h} - \dfrac{a(w - c - \varepsilon(g_m - g_0) + wt(g_m - g_0))}{p - h}, \\ \dfrac{\partial \pi_1}{\partial g_m} = \dfrac{a(p - w)(wt - \varepsilon)}{p - h} - 2\beta g_m. \end{cases} \tag{91.8}$$

Take second order partial derivative of with respect to w and g, we get the formula (91.9):

$$\begin{cases} \dfrac{\partial^2 \pi_1}{\partial {g_m}^2} = -2\beta, \\ \dfrac{\partial^2 \pi_1}{\partial \omega^2} = -\dfrac{2a(1 + t(g_m - g_0))}{p - h}, \\ \dfrac{\partial^2 \pi_1}{\partial \omega \partial g_m} = \dfrac{\partial^2 \pi_1}{\partial g_m \partial \omega} = \dfrac{atp - 2atw + a\varepsilon}{p - h}. \end{cases} \tag{91.9}$$

So $\dfrac{\partial^2 \pi_1}{\partial \omega^2} < 0$, $\dfrac{\partial^2 \pi_1}{\partial {g_m}^2} < 0$, and we get the Hessian Matrix:

$$\begin{vmatrix} \dfrac{\partial^2 \pi_1}{\partial \omega^2} & \dfrac{\partial^2 \pi_1}{\partial g_m \partial \omega} \\ \dfrac{\partial^2 \pi_1}{\partial \omega \partial g_m} & \dfrac{\partial^2 \pi_1}{\partial {g_m}^2} \end{vmatrix} > 0. \tag{91.10}$$

After calculating we found Hessian matrix is negative definite, so the manufacturer's profit is a concave function on greenness and the wholesale price, that is to say, there exist an optimal wholesale price w^* and greenness g_m^* to make maximum the value of manufacturer's profit. Then substitute w^* and greenness g_m^* to make maximum the value of manufacturer's profit. Then substitute w^* and g_m^* into formula (91.7), we can get seller's optimal order quantity y^*.

91.5 Example Analysis

91.5.1 Analysis Under the Variation of Government Subsidy

In order to analyze the influence on decision-making of manufacturers and sellers, under the variation of government subsidy, at the same time observe whether *a* greater subsidy will promote green supply chain members to produce high greenness products. Let unit product's subsidy coefficient adjustment factor t varies in [0.15, 0.6] and other parameters unchanged ($a = 100$; $p = 80$; $g_0 = 1$; $c = 50$; $h = 30$; $\varepsilon = 1$; $\beta = 50$). By using Matlab 7.0, this paper calculates the approximate solution of each formula. The calculation results are shown in Table 91.1.

As can be seen from the Table 91.1, with the increase of subsidy adjustment factor t, product's greenness g_m is on the rise, and when $t > 0.2$, the product wholesale price w continue to reduce, the seller's order quantity y further increase, manufacturers and sellers' expected profit were increased. This means that the government subsidies can greatly mobilize the enthusiasm of manufacturers to develop green products, and decreasing wholesale price lead sellers gradually replace the market

Table 91.1 Numerical analysis to government subsidy coefficient adjustment factor t

t	w	g_m	t	π_1	π_2
0	74.4444	−0.1111	11.1111	283.3351	30.8647
0.05	75.5883	0.2452	8.8235	204.259	19.4631
0.1	75.9873	0.5296	8.0254	169.6235	16.1018
0.15	74.7938	1.064	10.4123	208.3681	27.1045
0.2	69.0109	2.8137	21.9783	532.2987	120.7603
0.25	63.6949	4.8666	32.6101	1144.1451	265.8563
0.3	60.2303	6.749	39.5394	2007.059	390.841
0.35	57.9252	8.5093	44.1496	3119.3846	487.2968
0.4	56.3274	10.1939	47.3451	4475.9399	560.392
0.45	55.1783	11.8301	49.6434	6071.6638	616.1168
0.5	54.3254	13.4343	51.3492	7902.7428	659.1851
0.55	53.6753	15.0164	52.6494	9966.4111	692.9898
0.6	53.1684	16.5825	53.6632	12260.7214	719.9348

share, while consumers can buy green products with a cheaper price, so green supply chain which considered government subsidy can reduce the sales price of green products, stimulating consumption, improve the market share of green products, and increase the profits of enterprises, promote R&D and innovation of green technology, and finally improve the market competitiveness of enterprises. However, compared with the situation that without government's subsidy policy ($t = 0$), when the government subsidy coefficient adjustment factor is low (such as $t < 0.2$), the wholesale price of green products is higher and manufacturer and seller's profit is lower than before. This result indicates that, in order to better play the role of government participation, encourage manufacturers to develop green technology and green products, the government subsidies should reach a certain level, which is not only can ensure a more manufacturers revenue, but also can reduce the sales price of green products, so manufacturers, sellers and customers can benefit together, which also increased the management performance of green supply chain.

However, a too high subsidy adjustment factor will not only lead to a larger financial subsidy burden, but also prone to the phenomenon of excessive dependence on government subsidies, once the government subsidies decline or stop, manufacturers may be caught in a loss state. For example, ZHIGO Company always relies on subsidies to energy-saving air conditioning; in 2009 its total profit is more than 3 billion Yuan, however, after the subsidies policy adjustment to energy-saving in 2010, CHIGO Company's interim report display that it has stepped into a state of loss. Which means that, in order to promote the industrial structure adjustment, the government needs to set up a scientific and reasonable adjustment factor.

91.5.2 Analysis Under the Variation of Government Subsidy

In order to describe the impact that variation of g_0 on the supply chain, let g_0 varies range 0 to 1.6, the government's subsidy adjustment factor $t = 0.6$, the other variables are constant, Figs. 91.1, 91.2, 91.3 and 91.4 respectively describe the variables change

Fig. 91.1 Effect of the variation of g_0 on g_m

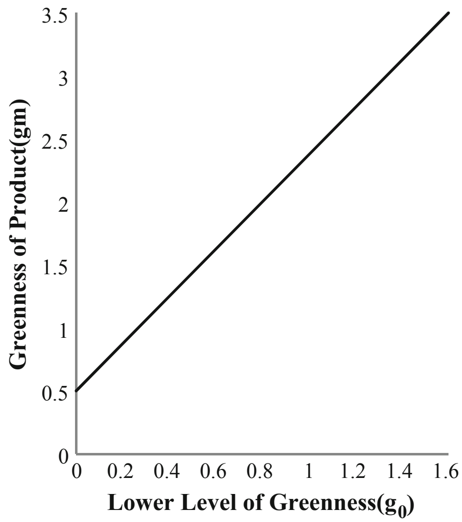
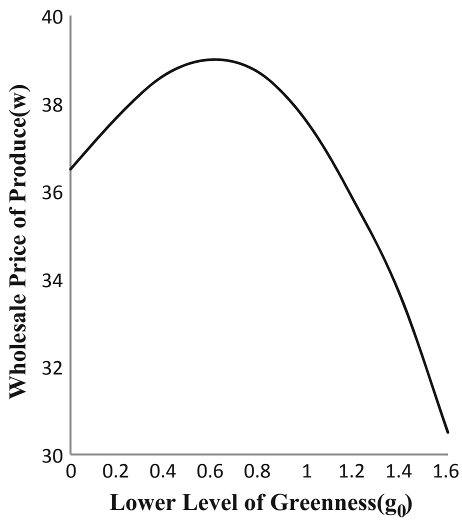


Fig. 91.2 Effect of the variation of g_0 on w



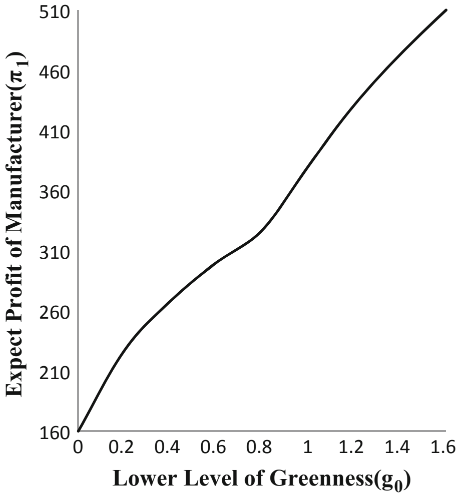


Fig. 91.3 Effect of the variation of g_0 on π_1

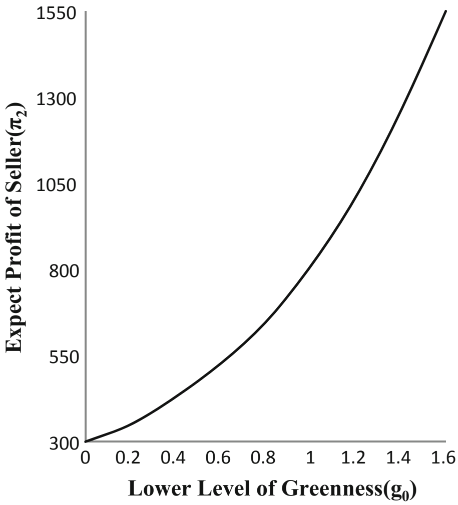


Fig. 91.4 Effect of the variation of g_0 on π_2

trend: the product's greenness level g_m, manufacturer's unit wholesale price w, manufacturer's expected profit π_1, seller's expected profit π_2. From Figs. 91.1, 91.2, 91.3 and 91.4, we can found that with the increasing of g_0, the product's greenness level g_m showed a gradual upward trend, the wholesale price w shows a trend from rise to decline, the expected profit of manufacturer and the retailer are all increased. Increased lower limit of greenness means the improving of subsidies access threshold, which will enable manufacturers to carry out more research and development innovation activities, enhance the greenness of products and gain more profits; on the other hand, increased lower limit of greenness can narrow the scope of government subsidies, so the unit product will receive more subsidies in the case of a certain amount of state financial subsidies, so the sale price of green products is lower and consumer demand is increased, which will increase seller's order quality. Therefore, in order to reduce the adverse effects of uncertain market demand on the supply chain members, the government can set a higher access threshold for subsidies, such as the policy of energy subsidies released in 2010, which stipulates to give subsidies to air conditioning which energy-saving level is above 1.

91.6 Conclusion

In his paper, we conduct a comprehensive consideration of various factors such as government subsidies, product's greenness and consumer demand uncertainty, then build a three-stage game model containing manufacturer, retailer and customer, and finally analyze the impact of demand uncertainty on the decision-making of supply chain members and the incentive mechanism of government participation. The results show that through increasing subsidies level and access threshold, the green supply chain members are willing to improve products' greenness level and order quantity, which is conducive to achieving social environmental goals. In order to better play the role of government participation in green supply chain management and achieve all-win, this paper put forward the following two recommendations:

(1) Firstly, the government should develop relevant policies, grasp the market information and promote green products in the whole society, the government should give a certain degree of subsidies to consumers who purchased products with a higher greenness level, improve people's environmental awareness, and set reasonable subsidy policy in fiscal, taxation, credit and other aspects, give biggest support to those companies who are willing to carry out green supply chain management. In the early stage of the green product consumption market, the government can set a lower threshold and a larger adjustment factors, so as to achieve the purpose of promoting industrial upgrading; when the green product market gradually mature, the task of optimizing industrial structure will shift from government-oriented to enterprise-dominant type, at that time the government need to gradually increase the lower subsidies limit, reduce the adjustment factor and finally withdraw the subsidy policy. At the same time, the government should implement strict environmental protection policy, increase the supervision, and force enterprises and consumers to carry out green supply chain management through coercive measures.

(2) Manufacturers need to realize that the government subsidy is a short-term behavior aiming to promote industrial transformation, under such tendency; manufacturers should continue to improve technical capabilities, develop better green products, enhance the core competitiveness of enterprises, and develop a long-term virtuous cycle so as to achieve the original intention of the government subsidy policy. At the same time, manufacturers should take efforts to control the risk of output fluctuations in the production process, which can achieve the greatest benefits in the changing market demand.

Obviously, there also exists some insufficient places, for example, the paper hasn't considered different levels of greenness may correspond to different product prices, and consumers may not be neutral preference to different greenness products, different levels of greenness will lead to different demand response. Also, this paper only takes single manufacturer and seller into account, so the further research can consider more members, which also can increase the game's possibility. This paper only analyzes the situation of the supply chain downstream, in fact, upstream of the supply chain can also be analyzed, such as the uncertainty of raw materials' supplement and so on. At the same time, manufacturers can consider not only the profit problem, but also the revenue stability as well as the stock out influence. These issues will become the research direction of the next step in the research of the green supply chain under the condition of the government subsidies.

References

1. Aspremont CD, Jacquemin A (1988) Cooperative and noncooperative R&D in duopoly with spillovers. Am Econ Rev 78(5):1133–1137
2. Ji J, Liu Q, Guo Z (2013) Performance appraisal of green supply chain management of steel enterprises. Sci Technol Manag Res 16:53–57
3. Jiang S, Li S (2015) Green supply chain game models and revenue sharing contract with product green degree. Chin J Manag Sci 6:169–176 (In Chinese)
4. Jin C, Wang F (2012) The analysis of enterprise decision-making and government incentive strategy in green supply chain. Forum Sci Technol China 3:74–80 (in Chinese)
5. Li Y, Zhao D (2013) Research of evolutionary game between governments and enterprises in the low-carbon supply chain. J Tianjin Univ (Soc Sci) 3:193–197
6. Mirhedayatian SM, Azadi M, Saen RF (2014) A novel network data envelopment analysis model for evaluating green supply chain management. Int J Product Econ 147:544–554
7. Saikis J (1998) Theory and methodology: evaluating environmentally conscious business practicees. Eur J Oper Res 107:159–174
8. Su L, Yang Z et al (2013) Research on factors affecting green technology collaboration of companies: viewed from supply chain. China Popul Resour Environ 6:149–154 (in Chinese)
9. Wang Y, Wang Y et al (2010) Green supply chain management review. China Popul Resour Environ 3:9–12 (in Chinese)
10. Ye F, Zhang J (2010) Research on the relationship among driving factors, green designing and green supply chain management performance. Stud Sci Sci 8:1230–1239
11. Zeng J, Liu J (2014) Research on the incentive mechanism of green supply chain based on government subsidies-perspective of random yield. J Nanchang Univ (Nat Sci) 5:430–437 (in Chinese)
12. Zuo Z, Liu C, Li J (2015) An empirical study of green cooperation performance and their influencing factors in cluster supply chain. Sci Sci Manag S&T 5:32–41 (in Chinese)

Chapter 92
Selection of Reverse Logistics Operating Channels Through Integration of Fuzzy AHP and Fuzzy TOPSIS: A Pakistani Case

Muhammad Nazam, Muhammad Hashim, Jamil Ahmad, Waseem Ahmad and Muhammad Tahir

Abstract In the emerging business environment, the organizations must promote alternative uses of resources that may be cost-effective and eco-friendly by extending products' routine life cycles. In this perspective, an efficient management of product returns through reverse logistics operating channels is a strategic issue. Business organizations including those of automobile manufacturing industries would like to focus on their core competency areas and there is need of making outsourcing decisions of their reverse logistics operating channels. There are five operating channels of reverse logistics; Supplier Operation, Manufacturer Operation, Distributor Operation, Third Party Operation and Joint Operation. The objective of this work is to develop the multi-criteria group decision support system to assist the top management of the company in selection of reverse logistics operating channels through integration of analytical hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS) under fuzzy environment. An illustrative case is included to validate the proposed method. The key findings and managerial insights of present study also enables the logistics managers to better understand the

M. Nazam (✉) · W. Ahmad
Institute of Business Management Sciences, University of Agriculture, Faisalabad 38000, Pakistan
e-mail: nazim_ehsas@yahoo.com

M. Hashim
Department of Business Administration, National Textile University, Faisalabad 38000, Pakistan

J. Ahmad
School of Economics, Bahauddin Zakariya University, Multan 60000, Pakistan

M. Tahir
Department of Business Administration, Federal Urdu University of Arts, Science and Technology, Karachi 74000, Pakistan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_92

complex relationships of the main attributes in the decision making environment and subsequently improve the reliability of the decision making process.

Keywords Reverse logistics · Operating channels · Automotive sector · Fuzzy AHP−TOPSIS

92.1 Introduction

In the past, supply chain process flow happens in the one way or forward direction only. Nowadays, industries are encountering the issues of return flow of the products in the supply chain for a variety of reasons like product recalls, warranty failure, guarantee failure, service failure, commercial returns, non-commercial returns, manufacturing returns, end-of-life and end-of-use returns. Reverse logistics is the process of return product handling mechanism in forward supply chain. Due to the growing environmental legislations, more attention is given to Reverse Logistics. Reverse Logistics (RL) is the process of planning, implementing and controlling the efficient, cost effective flow of raw materials, in process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value, or proper disposal [10].

The research of reverse logistics is in exploration stage. In Addition, cost minimization is possible in reverse logistics. A reverse logistics defines a supply chain that is redesigned to efficient manage the flow of products or parts designed for remanufacturing, recycling or disposal and to effectively utilize resources [11]. The various functions executed through RL activities include gate-keeping, compacting disposition cycle times, remanufacturing and refurbishment, asset recovery, negotiation, outsourcing and customer service [8].

In addition to disposition and transportation, value added services such as JIT, quick response and program solutions are also important functions in reverse logistics. Recovery of products for remanufacturing, repair and recycling can create profitable business opportunities. For managing the returns, the companies can reuse them, resell or destroy them. Retailers may return the goods due to seasonality, expiry or because of transit damage. Customers may return the goods due to poor quality. Managing the product returns increases the customer service level and retention level. Each activity from procurement to distribution generates waste and reduction of this waste is a major goal of environmentally conscious business practices [16]. Manufactures see reverse logistics as a process of recovering defective products or reusable containers back from the user. In the e-commerce since buyers need assurance for refund, reverse logistics is an important issue. Owing to R approach, this area present an opportunity for research. A conceptual framework for managing retail reverse logistics operation is presented in [12].

In the case study conducted by [1], three companies were visited and identified reverse logistics process flow and the strategic issues a firm may use for competitive advantage. An integrated forward logistics multi echelon distribution inventory supply chain model and closed loop multi echelon distribution for the built to order environment was designed using genetic algorithm and particle swarm optimization. A model for green supply chain management with incomplete information was developed [3]. Reverse logistics was suggested as an area for future research and the advantages of soft computing is its capability to tolerate imprecision, uncertainty [2]. A mathematical model for the design of Reverse Logistics network design was proposed [6, 9, 19] considering the location and allocation of facilities. A dynamic model was constructed and validated the same using the data collected from the computer company [18]. A distribution system which uses a combination of manufacturing and remanufacturing was proposed and the models were compared with respect to the various prices.

From the above references, studies have been done for the RL network design and the selection of third party logistics provider. But AHP and Fuzzy TOPSIS has not been used by any researcher for selection of RL operating channels selection. The companies can choose five operating channels for performing the RL activities (1) Supplier Operation collecting the raw material-Supplier Operation (2) Manufacturer collecting the used products-Manufacturer Operation (MO). (3) The distributor should control human resources, information systems and related equipment. (4) Outsourcing to third party-Third Party Operation (TPO). (e) Retailer will collect the used products- Joint Operation (JO). Remanufacturing costs may be reduced by third party. Since the third party logistics is using his latest technology and resource sharing advantages, uncertainty of recovery may be reduced. By outsourcing reverse logistics activities, the organizations can concentrate on their core business operation, but customer satisfaction and delivery performance may be improved. Third party reverse logistics provider will compete with each other in specific areas like price, quality and credit. Logistics costs will be reduced and order fill rate will be improved. Each channel has its distinct characters and suitable for companies with their sole service requirements. Evaluating and selecting reverse logistics channels is regarded as fuzzy multi criteria group decision making (FMCGDM) process in which a decision maker chooses the best option among the existing alternatives.

The rest of this paper is structured as follows. Following the introduction, in Sect. 92.2, the key problem for the automotive industry with different kinds of attributes in a reverse logistics under uncertain environment is described. The formulation of a fuzzy (MCGDM) model for selecting reverse logistics operating channels in a supply chain and its conversion into a crisp value can be explained in Sect. 92.3. In Sect. 92.4, a practical case study is presented to demonstrate the applicability of the proposed model. In the final section, the conclusions and directions for future research are discussed.

92.2 Problem Statement

In this problem, we classified the RL operating channels into five types based on the newly introduced attributes and as well as through literature review. Nowadays, profitable reuse and remanufacturing of automotive parts must meet the challenges of turbulent business environment which may includes continuous change in design pattern, frequent price fluctuations of new car models, disassembly of unfriendly designs, short life cycles, and prohibiting transport, labor and machining costs in high-wage countries. In current business environment, the remanufacturing of expensive, long-living investment machine/equipments, e.g., jet fans, machine tools, defense equipment or automobile engines, is extended to a large number of consumer goods with short life cycles and relatively low values. Reuse is an alternative to material recycling to comply with recovery rates and quantities as well as special treatment requirements.

Reverse Logistics can be applied to wide variety of industries like pharmaceutical, electronic, chemical, automobile and computer manufacturers. Automobile companies recover the end of life auto parts. Automotive products that contain hazardous materials are disposed. Reverse Logistics may take place through Supplier Operations (SO), Manufacturer Operation (MO), Distributor Operation (DO), Third Party Operation (TPO), and Joint Operation (JO). The criteria for the selection of RL operating channels have been found through literature review and experts discussions. The detailed classification of attributes is structured in Fig. 92.1.

92.3 Formulating a Fuzzy MAGDM Model for Selecting RL Operating Channels

This section proposes a methodology for selecting RL operating channels in the automotive sector. The methodology consists of three main stages as given in Fig. 92.2. The first step requires the firm to come up with a comprehensive hierarchy of all the criterion which may affect the firm. This is done by thoroughly studying the considered chain and identifying potential loopholes. These are then analyzed for overlaps and categorized using similar characteristics. This exercise should be repeated whenever a major change is made in the chain. The second step in the process involves assigning weights to the attribute according to their importance. Fuzzy AHP is used for this purpose and expert views are taken as input. The third step involves determining the scores of different criterion by analyzing them under five different attribute; namely logistics, financial, environmental, capacity, and alliances. In the fourth step fuzzy TOPSIS approach is employed to evaluate the organization's readiness of selecting RL operating channels [4]. Finally, comparison of results and managerial implications has been discussed.

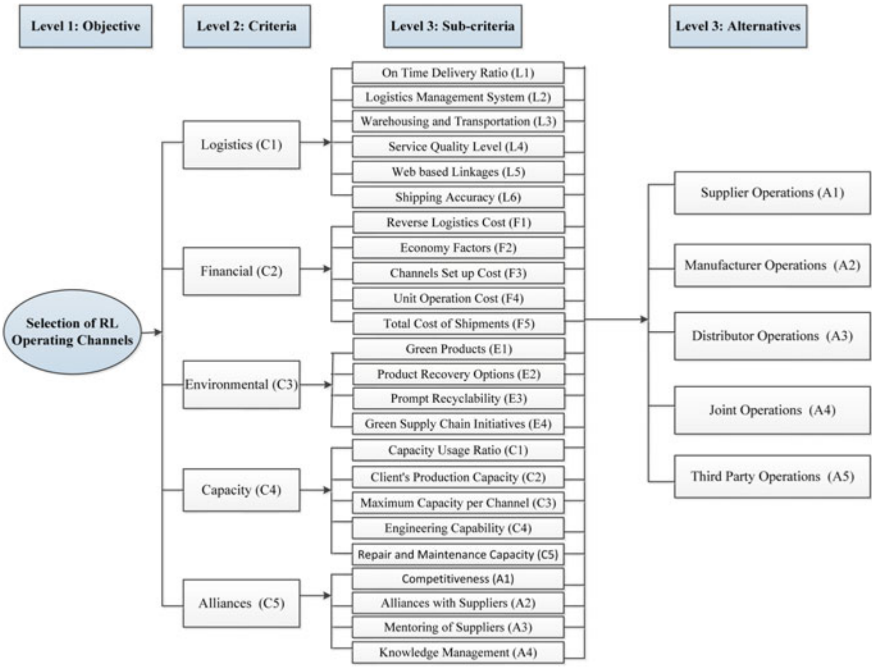


Fig. 92.1 The detailed classification of attributes

92.3.1 Fuzzy Hierarchical Approach for Selecting RL Operating Channels

In this section, an integrated fuzzy AHP-TOPSIS methodology is employed for selecting RL operating channels. In fuzzy AHP, fuzzy ratio scales are used to indicate the relative strength of the factors in the corresponding attribute. Therefore, a fuzzy judgment matrix can be constructed. The final scores of alternatives are also represented by fuzzy numbers. The optimum alternative is obtained by ranking the fuzzy numbers using special algebraic operators. In this methodology, all elements in the judgment matrix and weight vectors are represented by triangular fuzzy numbers.

Using fuzzy numbers to indicate the relative importance of one type over the other, a fuzzy judgment vector is then obtained for each criterion. These judgment vectors form part of the fuzzy pairwise comparison matrix which is then used to determine the weight of each criterion. Table 92.1 shows the meaning of linguistic expressions in the form of fuzzy numbers and Table 92.2 shows the random consistency index to calculate the consistency ratio (CR). Figure 92.3 represents the fuzzy membership function for linguistic expressions for attribute and sub-attribute. Experts are asked to give their assessment in the form of these linguistic expressions which are then converted and analyzed to finally get the weights. Chang's extent analysis method has been used for determining weights from pairwise comparisons (Table 92.3).

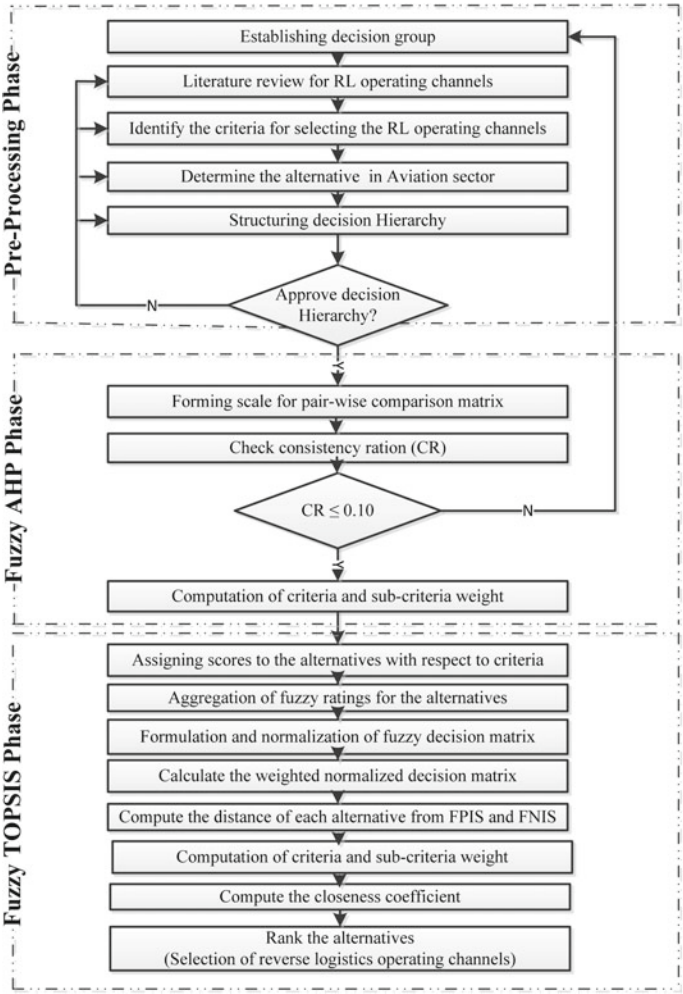


Fig. 92.2 The methodology consists of three main stages

Table 92.1 Scale for relative importance used in the pairwise comparison matrix

Intensity of importance	Fuzzy number	Linguistic variable	Triangular fuzzy numbers (TFNs)	Reciprocal of (TFNs)
1	$\tilde{1}$	Equally important	(1, 1, 3)	(0.33, 1.00, 1.00)
3	$\tilde{3}$	Weekly important	(1, 3, 5)	(0.20, 0.33, 1.00)
5	$\tilde{5}$	Strongly important	(3, 5, 7)	(0.14, 0.20, 0.33)
7	$\tilde{7}$	Very strongly important	(5, 7, 9)	(0.11, 0.14, 0.20)
9	$\tilde{9}$	Extremely more important	(7, 9, 11)	(0.09, 0.11, 0.14)

Table 92.2 The random consistency index

Size (n)	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40

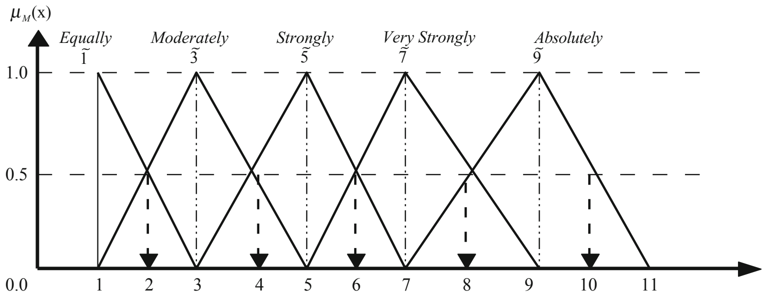


Fig. 92.3 Fuzzy membership function for linguistic expressions for attribute and sub-attribute

Table 92.3 Fuzzy evaluation scores for alternative

Linguistic variables	Corresponding TFNs
Very poor (VP)	(1, 1, 3)
Poor (P)	(1, 3, 5)
Medium (M)	(3, 5, 7)
Good (G)	(5, 7, 9)
Very good (VG)	(7, 9, 11)

For evaluating and ranking the alternatives, the fuzzy TOPSIS method is very suitable for solving real life application problems under a fuzzy environment. TOPSIS one of the classical multi-attribute decision making methods was developed by Hwang and Yoon [4]. Table 92.2 gives the linguistic scale for evaluation of the alternatives. Assuming that a decision group has K people, the ratings of alternatives with respect to each criterion can be calculated as Eq. (92.1).

$$\tilde{x}_{ij} = \frac{1}{K}\left[\tilde{x}_{ij}^{1}(+)\tilde{x}_{ij}^{2}(+)\cdots(+)\tilde{x}_{ij}^{k}\right], \tag{92.1}$$

where $\tilde{x}_{ij}^{k}$ is the rating of the K^{th} decision maker for i^{th} alternative with respect to j^{th} criterion. Obtaining weights of the attribute and fuzzy ratings of alternatives with respect to each criterion, the fuzzy multi-attribute decision-making problem can be expressed in matrix format as

$$\widetilde{D}=\begin{bmatrix}\tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n}\\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn}\end{bmatrix},\quad \widetilde{W}=[\tilde{w}_1,\tilde{w}_2,\ldots,\tilde{w}_n], \tag{92.2}$$

where $\tilde{x}_{ij}$ is the rating of the alternative A_i with respect to criterion j (i.e. C_j) and w_j denotes the importance weight of C_j. These linguistic variables can be described by triangular fuzzy numbers: $\tilde{x}_{ij}=a_{ij},b_{ij},c_{ij}$. To avoid the complicated normalization formula used in classical TOPSIS, the linear scale transformation is used here to transform the various attribute scales into a comparable scale. Therefore, we can obtain the normalized fuzzy decision matrix denoted by $\tilde{R}$

$$\tilde{R}=[\tilde{r}_{ij}]_{m\times n}, \tag{92.3}$$

where B and C are the set of benefit attribute and cost attribute, respectively, and

$$\tilde{r}=\left(\frac{\tilde{a}_{ij}}{c_j^*},\frac{\tilde{b}_{ij}}{c_j^*},\frac{\tilde{c}_{ij}}{c_j^*}\right),\quad j\ \varepsilon\ B, \tag{92.4}$$

$$\tilde{r}=\left(\frac{a_j^-}{c_{ij}},\frac{b_j^-}{b_{ij}},\frac{c_j^-}{a_{ij}}\right),\quad j\ \varepsilon\ C, \tag{92.5}$$

$$c_j^*=\max_i c_{ij},\quad \text{if } j\ \varepsilon\ B, \tag{92.6}$$

$$a_j^-=\min_i c_{ij},\quad \text{if } j\ \varepsilon\ C. \tag{92.7}$$

The normalization method mentioned above is to preserve the property that the ranges of normalized triangular fuzzy numbers belong to [0, 1].

Considering the different importance of each criterion, we can construct the weighted normalized fuzzy decision matrix as

$$\tilde{V}=[\tilde{v}_{ij}]m\times n,\quad i=1,2,\ldots,m;\ j=1,2,\ldots,n, \tag{92.8}$$

where

$$\tilde{v}_{ij}=\tilde{r}_{ij}(.)d(C_j). \tag{92.9}$$

According to the weighted normalized fuzzy decision matrix, we know that the elements $\tilde{v}_{ij}\forall,j$ are normalized positive triangular fuzzy numbers and their ranges belong to the closed interval [0, 1]. Then, we can define the fuzzy positive-ideal solution (FPIS, A^*) and fuzzy negative-ideal solution (FNIS, A^-) as

$$A^*=(\tilde{v}_1^*,\tilde{v}_2^*,\ldots,\tilde{v}_n^*), \tag{92.10}$$

$$A^-=(\tilde{v}_1^-,\tilde{v}_2^-,\ldots,\tilde{v}_n^-), \tag{92.11}$$

where

$$\tilde{v}_j^* = (1, 1, 1) \text{ and } \tilde{v}_j^- = (0, 0, 0) \tag{92.12}$$

The distance of each alternative from A^* and A^- can be currently called as

$$d_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^*), \quad i = 1, 2, \ldots, n, \tag{92.13}$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-), \quad i = 1, 2, \ldots, n, \tag{92.14}$$

where $d(.)$ is the distance measurement between two fuzzy numbers calculating with the following formula:

$$d(\tilde{\rho}, \tilde{\tau}) = \sqrt{\frac{1}{3}[(\rho_1 - \tau_1)^2, (\rho_2 - \tau_2)^2, (\rho_3 - \tau_3)^2]}, \tag{92.15}$$

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+}. \tag{92.16}$$

Obviously, an alternative A_i is closer to the (FPIS, A^*) and farther from (FNIS, A^-) as CC_i approaches to 1. Therefore, according to the closeness coefficient, we can determine the ranking order of all alternatives and select the best one from among a set of feasible alternatives.

92.4 Practical Application

The proposed model is developed to sort the solutions for selecting RL operating channels to deal its attributes. Based on the previous section, the practical application can be explained with numerical results as following.

92.4.1 Presentation of the Problem

A fuzzy multi-criteria group decision making (FMCGDM) model is applied to a real problem in industry. An electronics industry located in the western part of Pakistan is selected. The industry wanted a systematic way to implement the reverse logistics operations. Reverse Logistics brings significant improvements in the manufacturing process and the correct decisions made brings the industry competitive advantage. Therefore selecting the most important operating channels is of great importance for the industry. To collect the used auto spare parts and automobiles from the customers, the industry may choose Supplier Operation (SO), Manufacturer Operation (MO), Distributor Operation (DO), Third Party Operation (TPO) and Joint Operation (JO).

Nowadays, companies in Pakistan realize that physical distribution and reverse logistics management play a vital role in organization success and that selecting RL operating channels in supply chain is becoming an important activity. Only a few companies have adopted reverse logistics practices in integration with supply chain. But the success ratio is very low due to barriers selecting channels in supply chain. To improve the success rate it is essential to assess the attributes and solutions to overcome them. It is difficult to implement all attributes at the same time. Therefore, it is important and necessary to highlight these solutions of selecting RL operating channels, hence, Pakistani firms can focus on the prioritize solutions and implement them in a procedural way.

92.4.2 Case Solution

Phase 1. Identification of attributes and selection of RL operating channels

The decision group is composed of the 3 expert panel which comprising planning manager, production manager and logistics manager. In this study, through the panel discussion, the detailed sub-attribute under five main attribute (logistics, financial, environmental, capacity and alliances) were identified. The results are illustrated in Fig. 92.1, in which the hierarchy is descended from the general attribute in the second level to more detailed sub-attribute.

The overall objective of decision process determined as for selecting RL operating channels is in the first level of hierarchy. The main attribute on the second level, the sub-attribute at third level and alternative operating channels solutions in the fourth level of hierarchy See Fig. 92.1.

Phase 2. Calculation of the attribute weight by using fuzzy AHP

The committee members are asked to construct pair wise comparisons of five major attributes and 24 sub attributes by employing linguistic variables by using Tables 92.1 and 92.2. Through the arithmetic mean the pairwise comparison matrixes of attribute and sub attribute are established and given in Tables 92.4, 92.5, 92.6, 92.7, 92.8 and 92.9. The computational results got from the computations based on pairwise comparison matrixes provided in Tables 92.4, 92.5, 92.6, 92.7, 92.8 and

Table 92.4 Pairwise comparison matrix of the major criterion

	C_1	C_2	C_3	C_4	C_5
C_1	1	0.14	0.33	0.33	0.14
C_2	7	1	7	5	3
C_3	3	0.14	1	0.33	0.2
C_4	3	0.2	3	1	0.33
C_5	7	0.33	5	3	1

Table 92.5 Pairwise comparison matrix of the sub-attribute with respect to logistics attribute

	L_1	L_2	L_3	L_4	L_5	L_6
L_1	1	3	3	0.33	0.33	0.33
L_2	0.33	1	0.33	0.11	0.14	0.14
L_3	0.33	3	1	0.14	0.33	0.33
L_4	3	9	7	1	3	3
L_5	3	7	3	0.33	1	0.33
L_5	3	7	3	0.33	3	1

Table 92.6 Pairwise comparison matrix of the sub-attribute with respect to financial attribute

	F_1	F_2	F_3	F_4	F_5
F_1	1	3	9	5	9
F_2	0.33	1	5	3	9
F_3	0.11	0.20	1	0.33	3
F_4	0.20	0.33	3	1	7
F_5	0.11	0.11	0.33	0.14	1

Table 92.7 Pairwise comparison matrix of the sub-attribute with respect to environmental attribute

	E_1	E_2	E_3	E_4
E_1	1	0.14	0.14	0.11
E_2	7	1	1	0.33
E_3	7	1	1	0.33
E_4	9	3	3	1

Table 92.8 Pairwise comparison matrix of the sub-attribute with respect to capacity attribute

	C_1	C_2	C_3	C_4	C_5
C_1	1	3	7	3	7
C_2	0.33	1	7	3	3
C_3	0.14	0.14	1	0.33	0.33
C_4	0.33	0.33	3	1	3
C_5	0.14	0.33	3	0.33	1

Table 92.9 Pairwise comparison matrix of the sub-attribute with respect to alliances attribute

	A_1	A_2	A_3	A_4
A_1	1	0.11	0.11	0.14
A_2	9	1	1	0.33
A_3	9	1	1	0.33
A_4	7	3	3	1

Table 92.10 Weights of criteria and sub-criteria for selection of reverse logistics operating channels

Major criterion	Major criterion weight	Sub-attribute	Consistency	Ratio weight	Final weight	Ranking
Logistics	0.0392	L_1	0.0830	0.0986	0.0039	21
		L_2		0.0296	0.0012	24
		L_3		0.0592	0.0023	23
		L_4		0.4114	0.0161	12
		L_5		0.1641	0.0064	19
		L_6		0.2399	0.0094	17
Financial	0.5020	F_1	0.0995	0.5153	0.2587	1
		F_2		0.2660	0.1335	3
		F_3		0.0579	0.0291	10
		F_4		0.0579	0.0291	10
		F_5		0.0278	0.0140	15
Environmental	0.0655	E_1	0.0502	0.0379	0.0025	22
		E_2		0.2170	0.0142	14
		E_3		0.2190	0.0143	13
		E_4		0.5281	0.0346	8
Capacity	0.1208	C_1	0.0529	0.4799	0.0580	7
		C_2		0.2605	0.0315	9
		C_3		0.0415	0.0050	20
		C_4		0.1414	0.0171	11
		C_5		0.0766	0.0093	18
Alliances	0.2725	A_1	0.0989	0.0359	0.0098	16
		A_2		0.2325	0.0634	6
		A_3		0.2450	0.0668	4
		A_4		0.4990	0.1360	2

92.9, are shown in Table 92.10. Consistency ration values of all the matrices are less than 0.1, therefore, these matrices are sufficiently consistent.

Phase 3. Evaluation of the solutions of RL operating channels

The decision makers constructed a fuzzy evaluation matrix by taking linguistic variables shown in Table 92.3. It is constructed by comparing solutions under each of the attributes separately (See Table 92.11). Then transformed linguistic expressions into triangular fuzzy numbers and established the fuzzy evaluation matrix (See Table 92.12). Aggregate fuzzy weights of the alternatives are computed using Eq. (92.2) and presented in Table 92.13. In this study all the attribute are the barriers of selecting reverse logistics operating channels in supply chain, as per the goal minimization of these barriers is required. Hence, all the barriers are termed as cost attribute and normalization performed by Eq. (92.6) and for further detail (See Table 92.14). Next step is to obtain a fuzzy weighted evaluation matrix. Using the attribute weight calculated by fuzzy AHP (See Table 92.10), the weighted evaluation matrix is established using the Eq. (92.7) which is shown in Table 92.15.

Phase 4. Determination of final rank by fuzzy TOPSIS

In this study all the sub-attributes are the cost criteria. Hence, fuzzy positive-ideal solution (FPIS, A^*) and fuzzy negative-ideal solution (FNIS, A^-) as $\tilde{v}^* = (0, 0, 0)$ and $\tilde{v}^- = (1, 1, 1)$ for all these sub-criterion. Then compute the distance d of each alternative form FPIS and FNIS using the Eqs. (92.10) and (92.11). For example the distance $d_v\,(A_1, A^*)$ and $d_v\left(A_1, A^-\right)$ for alternative A_1 and sub-criteria M_1 from *FPIS* and *FNIS*, are calculated as follows.

$$d\left(A_1, A^*\right) = \sqrt{\frac{1}{3}(0 - 0.0008)^2 + (0 - 0.0023)^2 + (0 - 0.0039)^2},$$
$$d\left(A_1, A^*\right) = 0.00264,$$
$$d\left(A_1, A^-\right) = \sqrt{\frac{1}{3}(1 - 0.0008)^2 + (1 - 0.0023)^2 + (1 - 0.0039)^2},$$
$$d\left(A_1, A^-\right) = 0.99768.$$

Similarly, calculations are done for other sub-criterion for solutions of alternative A_1 and computed the cumulative distances of d_i^+ and d_i^- as $d_i^+ = 0.4725$ and $d_i^- = 23.6246$. By using the Eq. (92.12), the closeness coefficient (CC_i) of alternative A_1 computed as follows.

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} = \frac{23.6246}{23.6246 + 0.4725} = 0.98039.$$

The same procedure can be adopted to compute the distances and (CC_i) values of remaining alternatives. The final results are summarized in Table 92.16. Based on (CC_i) values rank the alternatives in descending order.

92.4.3 *Case Analysis*

In this section, the results derived for the proposed hybrid AHP-TOPSIS framework depict that A_3 has the highest coefficient closeness value, therefore selection of reverse logistics operating channels among the five alternative operating channels should be recommended. Therefore, based on the (CC_i) values, the ranking of alternatives in descending order are A_3, A_1, A_5, A_2 and A_4.

Table 92.11 Linguistic scale evaluation matrix for selection of reverse logistics operating channels

Sub-criterion		L1			L2			...	A1			A2		
Experts		E1	E2	E3	E1	E2	E3	...	E1	E2	E3	E1	E2	E3
Alternatives	A1	VP	P	VP	G	P	P	...	M	VP	VG	VP	VP	M
	A2	M	VP	M	P	M	VG	...	G	P	P	P	P	VG
	A3	G	VG	M	VP	P	G	...	P	VP	M	G	VP	M
	A4	P	M	VP	P	M	VP	...	VP	P	VG	P	P	VP
	A5	M	G	P	P	VP	M	...	P	M	M	VP	G	P

Table 92.12 Fuzzy evaluation matrix for selection of reverse logistics operating channels

	L1			L2			…	A1			A2		
	E1	E2	E3	E1	E2	E3	…	E1	E2	E3	E1	E2	E3
A1	(1, 1, 3)	(1, 3, 5)	(1, 1, 3)	(5, 7, 9)	(1, 3, 5)	(1, 3, 5)	…	(3, 5, 7)	(1, 1, 3)	(7, 9, 11)	(1, 1, 3)	(1, 1, 3)	(3, 5, 7)
A2	(3, 5, 7)	(1, 1, 3)	(3, 5, 7)	(1, 3, 5)	(3, 5, 7)	(7, 9, 11)	…	(5, 7, 9)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(1, 3, 5)	(7, 9, 11)
A3	(5, 7, 9)	(7, 9, 11)	(3, 5, 7)	(1, 1, 3)	(1, 3, 5)	(5, 7, 9)	…	(1, 3, 5)	(1, 1, 3)	(3, 5, 7)	(5, 7, 9)	(1, 1, 3)	(3, 5, 7)
A4	(1, 3, 5)	(3, 5, 7)	(1, 1, 3)	(1, 3, 5)	(3, 5, 7)	(1, 1, 3)	…	(1, 1, 3)	(1, 3, 5)	(7, 9, 11)	(1, 3, 5)	(1, 3, 5)	(1, 1, 3)
A5	(3, 5, 7)	(5, 7, 9)	(1, 3, 5)	(1, 3, 5)	(1, 1, 3)	(3, 5, 7)	…	(1, 3, 5)	(3, 5, 7)	(3, 5, 7)	(1, 1, 3)	(5, 7, 9)	(1, 3, 5)

Table 92.13 Fuzzy evaluation matrix for selection of reverse logistics operating channels

	L1	L2	⋯	A1	A2
A1	(1.00, 1.67, 5.00)	(1.00, 4.33, 9.00)	⋯	(1.00, 5.00, 11.0)	(1.00, 2.33, 7.00)
A2	(0.14, 0.27, 1.00)	(0.09, 0.17, 1.00)	⋯	(0.11, 0.23, 1.00)	(0.09, 0.20, 1.00)
A3	(0.09, 0.14, 0.33)	(0.11, 0.27, 1.00)	⋯	(0.14, 0.33, 1.00)	(0.11, 0.23, 1.00)
A4	(0.14, 0.33, 0.10)	(0.14, 0.33, 1.00)	⋯	(0.09, 0.23, 1.00)	(0.23, 0.42, 1.00)
A5	(0.11, 0.20, 1.00)	(0.14, 0.33, 1.00)	⋯	(0.14, 0.23, 1.00)	(0.11, 0.27, 1.00)

Table 92.14 Normalized fuzzy decision matrix for selection of reverse logistics operating channels

	L1	L2	⋯	A1	A2
A1	(0.20, 0.60, 1.00)	(0.11, 0.23, 1.00)	⋯.	(0.09, 0.20, 1.00)	(0.14, 0.42, 1.00)
A2	(0.14, 0.27, 1.00)	(0.09, 0.17, 1.00)	⋯	(0.11, 0.23, 1.00)	(0.09, 0.20, 1.00)
A3	(0.09,0.14,0.33)	(0.11,0.27,1.00)	⋯	(0.14,0.33,1.00)	(0.11,0.23,1.00)
A4	(0.14,0.33,0.10)	(0.14,0.33,1.00)	⋯	(0.09,0.23,1.00)	(0.23,0.42,1.00)
A5	(0.11,0.20,1.00)	(0.14,0.33,1.00)	⋯	(0.14,0.23,1.00)	(0.11,0.27,1.00)

Table 92.15 Weighted normalized fuzzy decision matrix for selection of reverse logistics operating channels

	L1	L2	⋯	A1	A2
A1	(0.0008, 0.0023, 0.0039)	(0.0001, 0.0003, 0.0012)	⋯	(0.0009, 0.0020, 0.0098)	(0.0091, 0.0272, 0.0634)
A2	(0.0006, 0.0011, 0.0039)	(0.0001, 0.0002, 0.0012)	⋯	(0.0011, 0.0023, 0.0098)	(0.0058, 0.0127, 0.0634)
A3	(0.0004, 0.0006, 0.0013)	(0.0001, 0.0003, 0.0012)	⋯	(0.0014, 0.0033, 0.0098)	(0.0070, 0.0146, 0.0634)
A4	(0.0006, 0.0013, 0.0039)	(0.0002, 0.0004, 0.0012)	⋯	(0.0009, 0.0023, 0.0098)	(0.0127, 0.0272, 0.0634)
A5	(0.0004, 0.0008, 0.0039)	(0.0002, 0.0004, 0.0012)	⋯	(0.0014, 0.0023, 0.0098)	(0.0070, 0.0173, 0.0634)

Table 92.16 Fuzzy TOPSIS results and final ranking for selection of reverse logistics operating channels

Alternatives	d_i^+	d_i^-	CC_i	Ranking
A1	0.4725	23.6246	0.98039	2
A2	0.5560	23.3963	0.97679	4
A3	0.4461	23.6477	0.98148	1
A4	0.5985	23.5331	0.97520	5
A5	0.5494	23.1490	0.97682	3

92.5 Conclusion

The evaluation and selection of the RL operating channels for automobile industry segment is a strategic management level decision. The e-waste is terribly increasing and it has become menace to community and green supply chain burden. Although financial and operational attributes are involved, the applicability of reverse logistics RL may be a dangerous activity for the industry. However growing environmental/green supply chain concerns have stimulate the industries to opt for reverse logistics operating channels. Nowadays the core agenda is by which channel the industries will be able to collect the required returned product.

The proposed methodology based on hybrid fuzzy AHP-TOPSIS is used for the selection of RL operating channels. The problem addressed in this research has been described as a fuzzy multi-criteria group decision making method under uncertainty, prompting the need for the method to handle imprecise judgments from experts.

Future research includes incorporating a two phase methodology combining fuzzy AHP-VIKOR and slightly carrying out sensitivity analysis to confirm the robustness in the relevant industries.

Acknowledgments The authors wish to thank the anonymous referees for their helpful and constructive comments and suggestions.

References

1. Amin M, Zahora Nasharuddin S (2013) Hospital service quality and its effects on patient satisfaction and behavioural intention. Clin Govern Int J 18(3):238–254
2. Andaleeb SS, Kara A (2014) The structure and measures of service quality perceptions for multiple-encounter services: a study of hospitals in bangladesh. Int J Healthc Manag 7(2):92–102
3. Bagozzi RP, Yi Y (1988) On the evaluation of structural equation models. J Acad Mark Sci 16(1):74–94
4. Bollen KA (2014) Structural equations with latent variables. Wiley, New York
5. Bollen KA, Long JS (1993) Testing structural equation models, vol 154. Sage
6. Breckler SJ (1990) Applications of covariance structure modeling in psychology: cause for concern? Psychol Bull 107(2):260

7. Cheng EW (2001) Sem being more effective than multiple regression in parsimonious model testing for management development research. J Manag Dev 20(7):650–667
8. EzPATH SJ (1989) A Supplementary Module for SYSTAT and SYSGRAPH (computer program). SYSTAT
9. Fornell C, Johnson MD et al (1996) The american customer satisfaction index: nature, purpose, and findings. J Mark, pp 7–18
10. Lt Hu, Bentler PM (1999) Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Eq Model Multidiscip J 6(1):1–55
11. Jöreskog KG (1970) A general method for analysis of covariance structures. Biometrika 57(2):239–251
12. Kazemi N, Ehsani P et al (2013a) Measuring hospital service quality and its influence on patient satisfaction: an empirical study using structural equation modeling. Manag Sci Lett 3(7):2125–2136
13. Lei P, Jolibert A (2012) A three-model comparison of the relationship between quality, satisfaction and loyalty: an empirical study of the Chinese healthcare system. BMC Health Serv Res 12(1):1
14. ML W (2011) Questionnaire statistical analysis and practicełSPSS operation and application. Chongqing University Press, Chongqing
15. Oliver RL (1980) A cognitive model of the antecedents and consequences of satisfaction decisions. J Mark Res, 460–469
16. Ping Jr RA (2015) A note on estimating second-order interactions and quadratics in latent variables. In: Assessing the different roles of marketing theory and practice in the jaws of economic uncertainty, pp 304–304. Springer, Heidelberg
17. Qin H, Prybutok VR et al (2014) UCPERF: An urgent care patient satisfaction instrument. Qual Manag J 21(3):11
18. Huo YB (2004) CSI model building and the GME comprehensive estimation research of its parameters. Master's thesis, Doctoral Dissertation of Nanjing University of Science and Engineering
19. Liu ZH (2015) Literature review of domestic and international research on patient satisfaction. Chin J Health Policy 8(4):60–66

Chapter 93
Fresh Produce Dual-Channel Supply Chain Logistics Network Planning Optimization

Xiaoya Sun and Chunxiang Guo

Abstract Considering the uncertainty of weather conditionsusing a robust optimization method to study the construction and design of the multi-objective dual-channel fresh produce supply chain network. Focusing on the problems of vendor selection and facility location-allocation of demand, the supply chain network robust optimization model has been established. By means of assigning different weights to the economic, environmental and customer satisfaction targets, determine the rational distribution of supply chain network under different weather circumstances and give the corresponding numerical examples. The results show that under different weather conditions, different goal weights will result in different network structures. Decision-makers can select the appropriate supply chain network structure according to their emphasis on different goals such as economy, environment and customer satisfaction.

Keywords Weather conditions · Supply chain network design · Robust optimization · Fresh produce · Multi-objective

93.1 Introduction

As the necessities of urban residents and important source of revenue of farmers, fresh produce has characteristics of perish ability, output volatility and demand points dispersibility. How to realize the circulation of fresh produce from producers to consumers quickly and efficiently has important practical significance of guaranteeing supply of urban residents, stabilizing prices and improving people's livelihood.

Since 1996 Zuurbier [6] first proposed the food supply chain, research on agricultural supply chain has increasingly become a hot topic of scientific research at home and abroad. Some scholars study the design and related policy issues of supply chain network structure from the supply chain stakeholders' perspective. Keizer

X. Sun · C. Guo (✉)
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: gchx1@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_93

[4] presented a new MILP model and a hybrid optimization-simulation approach to identify a cost-optimal network design under product quality requirements. LENG, Keizer [4] took the Fresh produce cold chain system as a research object, a non-linear programming mathematic model for logistics network nodes for fresh agricultural products was put forward, and corresponding genetic algorithm was designed. To solve ASCN design problems formulated by MIP model, Zhao, Dou [11] presented a hybrid particle swarm algorithm based approach. Based on this, to minimize the total cost of agri-food supply chain network (ASCN) and maximize the demand fill rate, Zhao, Cao [13] presented a multi-objective mixed integer linear programming model to optimize the multi-echelon ASCN with single product. The model integrates the decisions on facility location, capacity selection and transportation mode selection for logistics network.

The layout of Supply chain network design greatly affects the overall supply chain performance and efficiency. However, in the 21st century, with the national and the individual's emphasis on the environment and the diversification of customer needs, we not only take the economic costs as the starting point to measure the overall effectiveness of the supply chain, a growing number of scholars take supply chain as an integrated plan to carry out to reach overall supply chain optimization. Economy, environment and social responsibility has become the "three bottom line" during the Comprehensive development of the supply chain [8]. Govindan [2] introduced a two-echelon location-routing problem with time-windows for sustainable SCN design and optimizing economic and environmental objectives using heuristics in a perishable food SCN. Considering the maximization of the energy produced, the overall costs minimization and the mitigation of CO_2 emissions, Aldana [12] considered different technologies for converting the residues generated throughout the country into three possible products and develop a comprehensive MILP model. Aiming at the strong time-sensitive character of fresh agricultural products logistics distribution, Shao and Gao [3] taking the two goals that distribution cost minimum and customer satisfaction maximum into consideration, established a multi-objective optimization model of agricultural products distribution route.

Fresh produce has the characteristics of long production lead time and perishability, and it is affected by weather fluctuations and the supply chain layout strongly. Thus, the fresh produce supply chain network structure are becoming more complex. Any problem occurring in any link of supply chain will cause serious impact on the supply chain network and cause inconvenience to the life of the residents, and even affect the stability of the national economy and the smooth of national life. Thus enhancing the robustness of supply chain network and improving its anti-interference ability have important practical and theoretical significance to the supply chain management. Sazvar [7] considered inventory and transportation costs, as well as the environmental impacts under uncertain demand. The best transportation vehicles and inventory policy are determined by finding a balance between financial and environmental criteria. Zhao and Bao [10] took the produce circulation network of the northern Jiangsu area as the example, and analyzed the robustness of the existing agricultural products circulation network. To aim at the characteristic that adverse weather affects the outputs of agri-foods, Dan and Fu [1] firstly built a stochastic profit model for a two-stage agri-food supply chain that consists of a risk-adverse producer and a risk-neutral sales-agent. Then, they analyze the effects of adverse weather and producer's risk-adverse degree on optimal investment level and supply chain coordination. Due to the effect of uncertain factors such as seasonal weather, Zhao and Wu [9] addressed the issue of coordinating agri-food chain with perishable goods by revenue-sharing contract when both output and demand random factor are uniform distribution.

In summary, many scholars optimize the agricultural supply chain from the economic, environmental and customer service perspectives in the past. Some scholars consider the combination of the two aspects of them, present a multi-objective robust optimization model and solve it. However, no literature considering all three levels synthetically on agricultural supply chain network structure to optimize the design. In addition, the rise of the Internet bring enormous opportunities for the development of all walks of life, especially recently in the "Internet +" boom, local governments and businesses have been leveraging the "Internet +" to promote industry restructuring and deepen reform. Fresh produce industry is no exception. To seize the opportunity of using the Internet, local governments and businesses have introduced countermeasures, through the "Internet + production" and "Internet + Logistics", "Internet + Information" and other models, build agricultural supply chain, "O2O" mode [5]. The strategic stake in every orchard of Jingdong and the investment to fresh fruit Yi of Ali, etc., make the choice of consumers tend to be more diversified and personalized, which further exacerbated the complexity of the supply chain. Taking agricultural supply chain innovation and design issues into consideration during the era of the "Internet +" is a very important future research direction.

In this paper, aiming at the uncertainty of weather conditions, considering the online and offline sales channels of agricultural products, propose the robust optimization method to study the design of the supply chain network in the Internet context. The paper determines the rational distribution supply chain network when there're changes in weather conditions, including the issues of supply point selection and facility location-demand allocation etc. With the goals of minimizing economic and environmental cost, shortening the customer response time, we analyze the performance of the supply chain network.

93.2 Problem Description

To facilitate the study and without loss of generality, take the cooperation as the supplier which has its own agricultural planting base and can choose different environmental levels of seeds, fertilizers and other raw materials to plant agricultural products. Suppliers can select the appropriate customer area to build their own community supermarket and transport the agricultural products to the community supermarket to sale directly. Take the chain of supermarkets as the retailer which has its own online shopping platform of fresh produce. Consumers can search the agricultural products after entering the site, and at the same time, retailers can use the

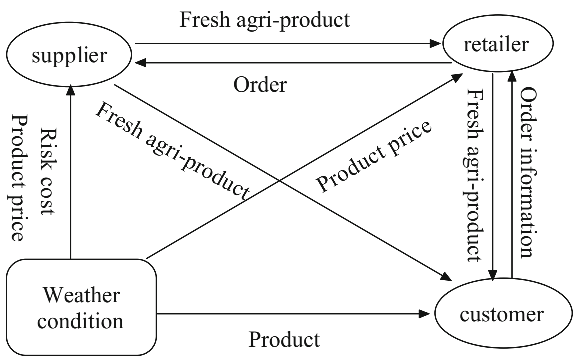


Fig. 93.1 The flow chart of fresh produce supply chain network

navigation system to locate the consumers' places, then consumer can find the retailers around him which can provide corresponding agricultural products to buy online. Suppose the operation process of fresh produce supply chain network is shown in Fig. 93.1. There are two channels available to get the fresh produce in customer area: Firstly, purchase directly from the community supermarket opened by the vendor; secondly, buy online through online sales platform developed by retailers. Retailers order products from the supplier according to the order of the customer area and then deliver the fresh produce to the customer area. The supplier's supply amount of products is affected by weather conditions, thereby affects the final price of fresh agricultural products. And the creation cost of community supermarket opened by supplier is also contained by weather conditions.

93.3 Modeling

Under the circumstance of supply uncertainty, assumed conditions for building models were included as follows:

(1) the needs of all customer areas are fully satisfied;
(2) Use different grades of green materials during fresh produce production process, representing different types of agricultural products;
(3) Unit storage and transportation costs of different types of agricultural are the same;
(4) Each vendor can only open up to one community supermarket in the customer area;
(5) Products can be sold out in the sales terminal;
(6) Each retailer/open community supermarket can be visited once in a given time period;
(7) Every line can be served only by a transport service;
(8) In the given time period, each retailer/open community supermarket can only have one car to provide services and the fresh produce required must be sent

once. The total demand of per delivery line can not exceed the vehicle carrying capacity;

(9) Roads are in good condition and smooth, the vehicle is at a constant speed during distribution;

(10) Suppliers do not store the product and their products are shipped out all;

(11) Don't consider the no-load cost and environmental no-load cost when the vehicle returns to the originating point.

Consider the supply uncertainty caused by weather conditions and competition, the problem was to establish the following issue: Take the supply chain as a whole, with the goal of minimizing the total economic and environmental costs of the system and maximizing customer service (in this paper, we only consider the arrival of lead). On the basis of meeting the constraints ability, how to determine the channel structure of the supply chain to make the performance of the supply chain be able to maintain stability in the parameter perturbations, thereby avoid market risks effectively. The typical decisions include facility siting (location, capacity); the distribution of demand and supply; the selection of suppliers and transport vehicle type.

Following symbols were used for convenience:

(1) Index definition:

m: supply spot, $m \in \{1, 2, \ldots, M\}$;

j: retailer spot, $j \in \{1, 2, \ldots, J\}$;

k: customer spot, $k \in \{1, 2, \ldots, K\}$;

i: vehicle type, $i \in \{1, 2, \ldots, I\}$

a: The type of raw material suppliers manufacture products used, set $a \in \{1, 2\}$, which represent two different environmental level, $a = 1$ represents high production cost, $a = 2$ represents low production cost, this paper use it to represent different types of products. h is weather condition, set $h \in \{1, 2, 3\}$, which indicates good weather, the general conditions, droughts or floods.

(2) Parameter determination:

f_{mk}: the fixed charge of community m supermarket opened by supplier in the customer area k;

fr^h_{mk}: the operational risk cost of opening community supermarket opened by supplier m in the customer area k, under the circumstance of weather h;

p^h_{jkia}: the sales price of product a transported from retailer a to customer area k by the vehicle type i, under the circumstance of weather h;

p^h_{mkia}: the sales price of product a transported from supplier m to customer area k by the vehicle type i, under the circumstance of weather h;

α^h_{ka}: the demand of customer area k about product a, under the circumstance of weather h;

g^h_{ma}: the maximum supply amount of product a in supplier m, under the circumstance of weather h;

dsf_{mj}: the distance between supplier m to retailer j;

dsf_{jk}: the distance between retailer j to customer area k;

dsf_{mk}: the distance between supplier m to customer area k;

kp_j: the inventory cost of unit product in retailer j;
kp_{mk}: the inventory cost of unit product in the community supermarket of customer area k opened by supplier m;
cgl_{mji}: the unit distance cost of unit product including transport from supplier m using the vehicle i to retailer j;
cgl_{jki}: the unit distance cost of unit product including transport from retailer j using the vehicle i to customer area k;
cgl_{mki}: the unit distance cost of unit product including transport from supplier m using the vehicle i to customer area k;
s_i: the average speed of vehicle i;
rt_{mji}: the replenishment time for the vehicle i from the supplier m to retailer j;
rt_{mki}: the replenishment time for the vehicle i from the supplier m to customer area k;
rt_{jki}: the replenishment time for the vehicle i from the retailer j to customer area k;
cap_j: the maximum inventory capacity of product in retailer j;
cap_{mk}: the maximum inventory capacity of product in community supermarket opened by supplier m of customer area k;
q_i: the maximum inventory capacity of product of vehicle i;
c_{ma}^h: the production cost of unit product of raw material a in supplier m, under the circumstance of weather h;
ve_{ma}^h: the environmental cost of producting per unit product of raw material a in supplier m, under the circumstance of weather h;
ie_j: the environmental cost of unit product storage in retailer j;
ie_{mk}: the environmental cost of unit product storage in community supermarket opened by supplier m of customer area k;
ef_{mk}: the environmental cost of opening the community supermarket opened by supplier m of customer area k;
et_i: the environmental cost of transporting unit product of unit distance by vehicle i;

(3) Decision variable:

$$x_{mk}^h = \begin{cases} 1, & \text{the community supermarket opened by supplier } m \text{ open of customer} \\ & \text{area } k \text{ under the circumstance } h \\ 0, & \text{else.} \end{cases}$$

$$y_{mki}^h = \begin{cases} 1, & \text{the product is transported by vehicle } i \text{ from supplier } m \text{ to customer} \\ & \text{area } k \text{ uncer the circumstance of weather } h, \\ 0, & \text{else} \end{cases}$$

$$y_{jki}^h = \begin{cases} 1, & \text{the product is transpoted by vehicle } i \text{ from retailer } j \text{ to customer area} \\ & k \text{ under the circumstance of weather } h, \\ 0, & \text{else} \end{cases}$$

$$y_{mji}^h = \begin{cases} 1, & \text{the product is transported by vehicle } i \text{ from supplier } m \text{ to retailer } j \\ & \text{under the circumstance of weather } h, \\ 0, & \text{else} \end{cases}$$

I_j^h: the inventory level of product in retailer, under the circumstance j of weather h;
I_{mk}^h: the inventory level of product in the community supermarket opened by supplier m of customer area k, under the circumstance of weather h;
u_{mjia}^h: the freight volume of product a transported by vehicle from supplier m to retailer j, under the circumstance of weather h;
w_{jkia}^h: the freight volume of product a transported by vehicle from retailer j to customer area k, under the circumstance of weather h;
v_{mkia}^h: the freight volume of product a transported by vehicle from supplier m to customer area k, under the circumstance of weather h;

The model aimed at the least total cost, the least environmental cost of supply chain network, the shortest replenishment time of customer, defining objective function as follows:

$$\begin{aligned}\min\ \mathrm{OBJ}_h1 = &\sum_m\sum_k f_{mk}x_{mk}^h + \sum_m\sum_k fr_{mk}^h x_{mk}^h + \sum_m\sum_j\sum_i\sum_a cgl_{mji}dsf_{mj}u_{mjia}^h \\ &+ \sum_j\sum_k\sum_i\sum_a cgl_{jki}dsf_{jk}w_{jkia}^h + \sum_m\sum_k\sum_i\sum_a cgl_{mki}dsf_{mk}v_{mkia}^h x_{mk}^h \\ &+ \sum_j kp_j I_j^h + \sum_m\sum_k kp_{mk}I_{mk}^h x_{mk}^h + \sum_m\sum_a\sum_i c_{ma}^h(\sum_j u_{mjia}^h + \sum_k v_{mkia}^h x_{mk}^h) \\ &- \sum_j\sum_k\sum_i\sum_a p_{jkia}^h w_{jkia}^h - \sum_m\sum_k\sum_i\sum_a p_{mkia}^h v_{mkia}^h x_{mk}^h \end{aligned} \tag{93.1}$$

$$\begin{aligned}\min\ \mathrm{OBJ}_h2 = &\sum_m\sum_a\sum_i ve_{ma}^h(\sum_j u_{mjia}^h + \sum_k v_{mkia}^h x_{mk}^h) + \sum_j ie_j I_j^h \\ &+ \sum_m\sum_k ie_{mk}I_{mk}^h x_{mk}^h + \sum_m\sum_k ef_{mk}x_{mk}^h \\ &+ \sum_a\sum_i et_i\left(\sum_m\sum_j dsf_{mj}u_{mjia}^h + \sum_j\sum_k dsf_{jk}w_{jkia}^h + \sum_m\sum_k dsf_{mk}v_{mkia}^h x_{mk}^h\right), \end{aligned} \tag{93.2}$$

$$\begin{aligned}\min\ \mathrm{OBJ}_h3 = &\sum_m\sum_j\sum_i (rt_{mji}\sum_a u_{mjia}^h + \frac{dsf_{mj}}{s_i})y_{mji}^h \\ &+ \sum_j\sum_k\sum_i (rt_{jki}\sum_a w_{jkia}^h + \frac{dsf_{jk}}{s_i})y_{jki}^h + \sum_m\sum_k\sum_i (rt_{mki}\sum_a v_{mkia}^h + \frac{dsf_{mk}}{s_i})y_{mki}^h. \end{aligned} \tag{93.3}$$

The objective function (93.1) is to minimize the economic cost of the whole supply chain network. The first item represented the fixed cost of opening up community supermarket under the circumstance of weather h; the second item represented the operational risk cost caused by the weather condition; the third, fourth and fifth items represented the transportation cost from supplier to retailer, from retailer to customer area and from supplier to customer area, respectively. The sixth and seventh items referred to inventory cost of retailer and community supermarket, respectively; the eighth item represented the production cost in supplier; the ninth and tenth items referred to the total sales revenue of retailer in the customer area and supplier in the community supermarket, respectively. Because the objective function is to get the minimum value, so the last two items need to be deducted from the total cost.

The objective function (93.2) is to minimize the environmental cost of the whole supply chain network. The first item represented the productive environmental cost of supplier; The second and third items referred to the environmental cost of storing products by retailer and community supermarkets, respectively. The fourth item represented the environmental cost of opening up community supermarket by supplier; The fifth item referred to the environmental cost of transporting products from supplier to retailer, from retailer to customer area and from supplier to community supermarkets, respectively.

The objective function (93.3) is to shorten the customer replenishment time of the whole supply chain network. The first item represented the replenishment time and transportation time from supplier to retailer; The second item referred to the replenishment time and transportation time from supplier to community supermarket opened by the corresponding supplier; The third item represented the replenishment time and transportation time from retailer to customer area.

Specific variable constraint was shown as follows:

$$\sum_i \sum_j w^h_{jkia} + \sum_i \sum_m v^h_{mkia} x^h_{mk} \geq \alpha^h_{ka}, \forall k, a, h, \tag{93.4}$$

$$\sum_i \sum_j u^h_{mjia} + \sum_i \sum_k v^h_{mkia} x^h_{mk} \leq g^h_{ma}, \forall m, a, h, \tag{93.5}$$

$$\sum_m \sum_i u^h_{mjia} = \sum_k \sum_i w^h_{jkia}, \forall j, a, h, \tag{93.6}$$

$$I^h_j \leq \text{cap}_j, I^h_{mk} \leq \text{cap}_{mk} x^h_{mk}, \forall m, j, k, h, \tag{93.7}$$

$$\sum_a u^h_{mjia} \leq q_i y^h_{mji}, \sum_a w^h_{jkia} \leq q_i y^h_{jki}, \sum_a v^h_{mkia} \leq q_i x^h_{mk} y^h_{mki}, \forall m, j, k, i, h, \tag{93.8}$$

$$\sum_k x^h_{mk} \leq 1, \sum_i y^h_{mki} \leq 1, \sum_i y^h_{mji} \leq 1, \sum_i y^h_{jki} \leq 1, \forall m, j, k, i, h, \tag{93.9}$$

$$x^h_{mk} \in \{0, 1\}, y^h_{mki} \in \{0, 1\}, y^h_{mji} \in \{0, 1\}, y^h_{jki} \in \{0, 1\}, y^h_{mji} \in \{0, 1\}, \forall m, j, k, i, h, \tag{93.10}$$

$$I^h_j, I^h_{mk}, u^h_{mjia}, w^h_{jkia}, v^h_{mkia} \geq 0, \forall j, h, m, k, i, a \tag{93.11}$$

Demand constraint of customer was shown in Eq. (93.12); Production capacity constraint in supplier was shown in Eq. (93.5); Eq. (93.6) represented the products amount transported form supplier to retailer was equal to the product amount transported from retailer to customer area; Eq. (93.7) stood for maximum inventory capacity limitation of products in retailer and community supermarkets opened by supplier, respectively; Eq. (93.8) stood for maximum capacity limitation of vehicles;

Eq. (93.9) stood for limitation of vehicles' numbers from supplier to community supermarket, from supplier to retailer and from retailer to community supermarkets, respectively; Eq. (93.10) were 0–1 variable constraints, while Eq. (93.11) defined the variable types.

The model could be solved by Lingo language, determining quantity and situation of facilities in fresh produce supply chain networks. Thus rational layout of supply chain network was obtained.

93.4 Robust Optimization Model of Fresh Produce Supply Chain Network Under Uncertain Information Environment

Fresh produce is the product which was needed most and consumed largest by residents in China in addition to food and it plays an important role in the structure of consumption in daily life of people. With the continuous development of the national economy and people's living standards improve, people have made diversified requests on the quality, carbon labeling and other aspects of the fresh produce. Especially with the rapid development of Internet industry in recent years, more people are seeking for more personalized, convenient consumption manner. The number of purchasing fresh produce online continues to increase, triggering a new round of innovative of sales and distribution in produce supply chain network. The action of major electricity fresh supplier is constant, for example, Jingdong stake in every orchard strategically, Ali invests in fresh fruit and so easy to Easy fruit fresh, and so on, which forms the competition with the traditional sales way of fresh produce to a certain degree. Beyond that, fresh produce itself has the characteristics of decentralized production and consumption, less product differentiation, strong seasonality and so on, in particular, its longer growing period is easily influenced by weather conditions and other natural conditions, resulting in the volatility of fresh produce yield, the change of supply volume in turn leads to change in price, making it easier to be turbulent and cracked for fresh produce supply chain.

In view of complicated uncertain factors, fresh produce supply chain's ability of maintaining original function became doubtful when facing environmental changes. Robust optimization model of fresh produce supply chain network was set up in this section, using risk decision theory under uncertain condition. Considering the changing of weather condition, the work designed an optimal network structure to resist uncertainty and keep favorable benefit.

The probability of each objective function in weather situation h were assumed as p_1, p_2, and p_3 in fresh produce supply chain network, then weigh the sum of three objective functions. The definition of deterministic model in fresh produce supply chain network was defined as follows:

$$DM: \ \min \ \mathrm{OBJ} = p_1\mathrm{OBJ}_h 1 + p_2\mathrm{OBJ}_h 2 + p_3\mathrm{OBJ}_h 3 \tag{93.12}$$
$$s.t.(94.12) \sim (94.11)$$
$$p_1 + p_2 + p_3 = 1.$$

Set optimal objective function as OBJ_h^* that corresponded to every situation. Variable $\theta = \{x_{mk}^h, I_j^h, I_{mk}^h, u_{mjia}^h, w_{jkia}^h, v_{mkia}^h\}$ was a feasible solution to the model (93.12), corresponding to objective function $\mathrm{OBJ}_h(\theta)$.

Here, take the expected total cost of the system as an optimization goal, to get the optimal network optimization structure of different weights, and to investigate the robustness of the solution obtained in different weather conditions and different weight ratio, so we can to provide guidance to the decision-makers who have different preferences.

93.5 Examples Analysis

The given example aimed at illustrating following problems: (1) the effect of weather condition on construction of fresh produce supply chain networks; (2) the performance of robust model of fresh produce chain network under different weather situations.

It was assumed that there're three suppliers, two retailers and three customer areas. Single or multi type raw materials were available in every supply spot. There're three vehicle types which have different speeds. Maximum inventory volume of retailers and community supermarkets was 2000 and 500 respectively. Maximum production capacity in suppliers was 1500, 1000 and 1200, respectively. Weather situation contained three situations: good weather, the general conditions, droughts or floods. As Table 93.1 showed, uncertain factors presented three different situations based on weather situation, including customer demand, operational risk cost. Due to limited space, the other argument is omitted.

Table 93.1 Risk costs under the impact of weather condition

			Weather 1	Weather 2	Weather 3
Community supermarkets opening up costs	Customer area 1	Supplier 1	500	600	700
		Supplier 2	400	600	800
		Supplier 3	600	700	700
	Customer area 2	Supplier 1	450	550	650
		Supplier 2	350	550	750
		Supplier 3	550	650	650
	Customer area 3	Supplier 1	400	500	600
		Supplier 2	300	500	700
		Supplier 3	500	600	600

Under given weather situation, supply chain network model of fresh produce industry was a traditional 0–1 mixed integer programming problem with large scale. Lingo method was employed to solve the problem.

When good weather situation occurred, 209 variables were obtained in the INLP model, including 72 integer variables and 115 constraints.

As it can be seen from Table 93.2, when the target weight is the same, on the whole, the total targets obtained from small to large occurred in the droughts or floods, good weather and general condition, respectively. Contrast can be seen in Table 93.1, when the weather conditions are bad, the customer's demand would be reduced, or even the individual case needs are not met, so that transportation and storage costs decrease. When the target weights are 1, 0, 0, the result is negative, because the first goal, the economic cost is obtained from the cost minus income, and the economic cost is less than the revenue values. When the weather conditions are the same, with the given weight to the first objective function value decreases, the weight to the second objective function gradually increase, the total target value also increases slowly. It shows that when the nodes of supply chain pay more attention to the environment, the cost increases correspondingly. When the target weights are 0, 0, 1, indicating the supply chain subjects only consider the customer response time, which is related to the transportation amount of products, as weather conditions changing from good to bad, the traffic amount declines and the response time is also reduced. However, the satisfaction of customer needs may not be met.

As can be seen from the computational results, in most cases, the supply chain objects choose the third type of the vehicle for transport.

Consider that the order of magnitudes of the first two objective functions are much larger than the third objective function, the unit transportation cost and the unit environmental cost of the third vehicle is low, especially when the weight given to the environmental objective cost exceeds 0, all the vehicles should be chosen the third type. When the weight given to the environmental objective is equal to 0, if we give the weight 1 to the economical objective, then considering the total transportation costs and total revenues, the supply chain subjects will choose the third and the second vehicles at the same time, and the unit transportation cost of the latter is higher than the third type vehicle, but the sales price of the product transported by the second type vehicle is higher than the third one. If we give the weight 1 to the response time of customers objective, then the supply chain subjects should choose the first type vehicle whose speed is the fastest.

In addition, it can be seen from the computational results, in most cases, policy-makers should ship the products to retailers, and then the retailers conduct the offline distribution according to the customer online orders, only when the weights given to the environmental objective and the customer response time objective are much bigger than the weight given to the economical objective, the vendors should select to open up the community supermarkets. Because the distance of transporting the products directly to the community supermarkets of the customer locations is less than the sum of distance from the suppliers to retailers and from the retailers to the customer areas, it is the decision obtained after trading off the total environmental cost caused by transportation and opening up the community supermarkets. Besides,

Table 93.2 The objective function values for different weights under different weather conditions

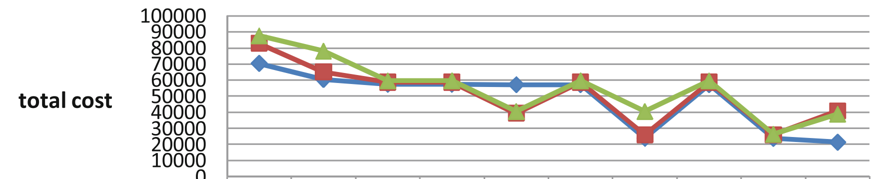
Weight	(1, 0, 0)	(0.8, 0.1, 0.1)	(0.6, 0.2, 0.2)	(1/3, 1/3, 1/3)	(0.2, 0.6, 0.2)	(0.2, 0.2, 0.6)	(0.1, 0.8, 0.1)	(0.1, 0.1, 0.8)	(0, 1, 0)	(0, 0, 1)
Good weather	−11650	8056	22502	41403	76857	24845	102001	12427	125725	4.55
General conditions	−11000	8876	23637	42628	78477	25581	103746	12796	127700	4.49
Droughts or floods	−13700	6813	21983	40805	75465	24487	99885	12287	122985	4.43

because of the creation of the community supermarkets, customers can go directly to the community supermarkets to buy the products which reduces the replenishment time and the transportation time of long-distance between suppliers and retailers after the customers' purchase request. Consider this factor, when the supply chain subjects attach importance to the response time of customer, we should choose to open up the community supermarkets.

In addition, for the results of the network layout in each specific case, the income and its trends can intuitively conclude from the following table.

From Figs. 93.2, 93.3 and 93.4, we can see that when weather conditions are the same, with the right conferred on economic targets gradually decreased, these income items are gradually declining. As can be seen from Fig. 93.2, generally speaking, the income when there're droughts or floods is higher than the other two weather conditions, because the production and transportation costs of the products when there're droughts or floods are higher than the other two cases and the corresponding sales price is higher, too, resulting the revenue is far more when the weather is bad. Contrast to Figs. 93.3 and 93.4 we can see that, the sales revenues of the first and the second product are exactly opposite under different weather conditions. When the weather is better, the suppliers and retailers prefer to sale the first type of products, that is, the high degree of environmental protection products. However, when the weather is worse, the supply chain subjects are prefer to sale the low degree of environmental protection products. This is because the cost of high grade environmental protection produced by the suppliers is higher and the risk of sales is greater when the weather is bad.

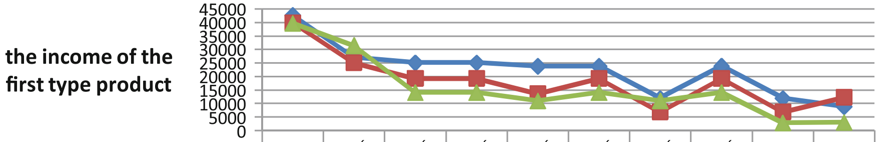
In addition, from the results we can see that, only if when the customer response time goal is given the weight 1, there're will be stocks in the supermarkets opened



	（1,0,0）	（0.8,0.1,0.1）	（0.6,0.2,0.2）	（1/3,1/3,1/3）	（0.2,0.6,0.2）	（0.2,0.2,0.6）	（0.1,0.8,0.1）	（0.1,0.1,0.8）	（0,1,0）	（0,0,1）
good weather	70450	60500	57500	57500	57250	57250	23950	57250	23950	21500
general condition	82950	65150	58800	58800	39500	58800	26150	58800	26150	41000
droughts or floods	87700	78200	59670	59670	40470	59720	40470	59720	26350	38900

objective weights

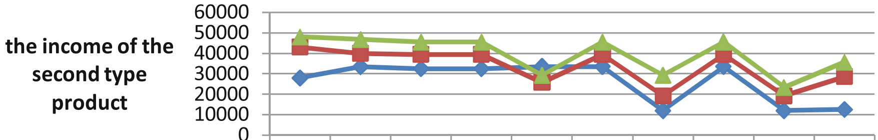
Fig. 93.2 Total income changes for different target weights under different weather situations



	（1,0,0）	（0.8,0.1,0.1）	（0.6,0.2,0.2）	（1/3,1/3,1/3）	（0.2,0.6,0.2）	（0.2,0.2,0.6）	（0.1,0.8,0.1）	（0.1,0.1,0.8）	（0,1,0）	（0,0,1）
good weather	4260	2720	2515	2515	2385	2385	1200	2385	1200	9000
general condition	3990	2515	1930	1930	1370	1930	6950	1930	6950	1240
droughts or floods	3965	3145	1412	1412	1112	1412	1112	1412	3000	3200

objective weights

Fig. 93.3 The changes of the first type product income for different target weights under different weather situations



	（1,0,0）	（0.8,0.1,0.1）	（0.6,0.2,0.2）	（1/3,1/3,1/3）	（0.2,0.6,0.2）	（0.2,0.2,0.6）	（0.1,0.8,0.1）	（0.1,0.1,0.8）	（0,1,0）	（0,0,1）
good weather	2785	3330	3235	3235	3340	3340	1195	3340	1195	1250
general condition	4305	4000	3950	3950	2580	3950	1920	3950	1920	2860
droughts or floods	4805	4675	4555	4555	2935	4555	2935	4560	2335	3570

objective weights

Fig. 93.4 The changes of the second type product income for different target weights under different weather situations

by the suppliers. The existence of stockpiles ensures that the customers don't have to wait when purchasing the products, so we can get the shortest response time, which causes the production of inventory cost at the same time.

93.6 Conclusions

Fluctuation of weather condition results in change of fresh produce demand and operation risk, advent of the Internet age + adds complexity and multi-channel of the entire fresh produce supply chain network. This work studied design of online and offline two-channel supply chain network in the context of Internet considering the effect of weather fluctuation. The aim of the study lied in determining optimal channel structure and taking uncertain parameters into account. Thus performance of supply chain network possessed robustness under parameter perturbation situation.

Following conclusions are obtained:

(1) Different weather situations that aim at minimum economic and environmental cost and shorten the customer response time present various network structures in determined supply chain network models;
(2) The different attentions to the economic, environmental and customer satisfaction degree makes the network structure different even the weather conditions are the same. Decision-makers can select corresponding supply chain network structure according to their degree of attention for different targets. Usually only when decision-makers attach great importance to environmental costs and customer response time, they will choose to open a community supermarket in the vicinity of the customer location, in most cases they should select the replenishment of distribution offline according to the customer online order.
(3) The impact of weather conditions will also affect the choice of product range which would be sold. To reduce the risk and the production and transportation cost, when the weather conditions are poor, suppliers are more likely to choose the lower degree of quality and lower cost of products to sale.

This research is a study carried out for fresh produce network, next the perishable nature of fresh produce may be taken into account, as an indicator of customer satisfaction research. Additionally, on arithmetic processing for multi-target model, this article uses the method of decentralization weight sum for a multiple destination options, this will help decision-makers choose different network structures according to their own preferences. However such an approach can't be easy to meet more accurate solution. The future research may consider other intelligent algorithms to deal with related problems in order to draw further conclusions.

Acknowledgments The authors thank the anonymous referees for their constructive suggestions. We appreciate the support provided for this paper by the National Natural Science Funds of China (Project Nos. 71471123 and 71071102); and the Sichuan province philosophy social sciences key research base (XHJJ-1507).

References

1. Bin D (2014) The coordination of agricultural supply chain whose output is impacted by weather under the risk aversion. Syst Eng 3:362–370
2. Govindan K, Jafarian A et al (2014) Two-echelon multiple-vehicle location-routing problem with time windows for optimization of sustainable supply chain network of perishable food. Int J Product Econ 152(2):9–28
3. Juping S (2015) VRP model and algorithm in fresh produce distribution with time windows. Ind Eng Manag 1:122–127+134 (in Chinese)

4. Keizer MD, Haijema R et al (2015) Hybrid optimization and simulation to design a logistics network for distributing perishable products. Comput Ind Eng 88:26–38
5. Liu Z, Gong H (2015) The process integration optimization of 'O2O' type agricultural supply chain under the 'Internet +' concept. Seeking 6:90–94 (in Chinese)
6. Salin V (1998) Information technology in agri-food supply chains. Int Food Agribus Manag Rev 01(3):329–334
7. Sazvar Z, Baboli A et al (2014) A bi-objective stochastic programming model for a centralized green supply chain with deteriorating products. Int J Product Econ 150(6):140–154
8. Wu Z, Pagell M (2011) Balancing priorities: decision-making in sustainable supply chain management. J Oper Manag 29(6):577–590
9. Xia Z, Wu F (2009) The revenue sharing contract research coordination of agricultural supply chain under random output and demand. China Manag Sci 17(5):88–95 (in Chinese)
10. Zhao G, Bao X, Yang YB, (2014) The robustness and topological structure evolution of agricultural distribution network. Jiangsu Agric Sci 10:405–407 (in Chinese)
11. Zhao Xia, Dou J (2013) The hybrid particle swarm optimization of solving agricultural supply chain network design problem. Manag Technol 4:169–177
12. Aldana H, Lozano FJ, Acevedo J (2014) Evaluating the potential for producing energy from agricultural residues in mexico using milp optimization. Biomass Bioenergy 67:372–389
13. Zhao X, Cao B, Dou J (2015) The multi-target optimization design of agricultural supply chain network based on swarm intelligence. Comput Integr Manufact Syst 9:2525–2527 (in Chinese)

Chapter 94
Company Z Storehouse Center Layout Optimization

Jianguo Zheng and Wanhua Zhang

Abstract The modern storehouse provides not only the traditional storage service, but also other value-added services such as package, OEM, and customer service, which are related to postponement strategy of manufacturing, so as to improve customer satisfaction. Storehouse is a value-added service center in the supply chain. This paper aiming at Company Z storehouse center activity and management problems, using the system facility planning layout SLP (systematic layout planning) method, optimizes the layout of Company Z storehouse center, improves the efficiency of Company Z storehouse center activity and management, and increases revenue for the enterprise.

Keywords Storehouse center · Layout · Optimization · Efficiency

94.1 Current Situation and Problems of Company Z Storehouse Layout

Our team did three days' research in Company Z storehouse center, recorded storage center activity and management process in details, and drew a map of Company Z storehouse layout (see Fig. 94.1).

Storehouse activity and management problems in Company Z storehouse layout are as follows:

J. Zheng (✉)
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: Joan1221@sina.com

W. Zhang
XinBeiCun, Sichuan University, Chengdu 610065, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_94

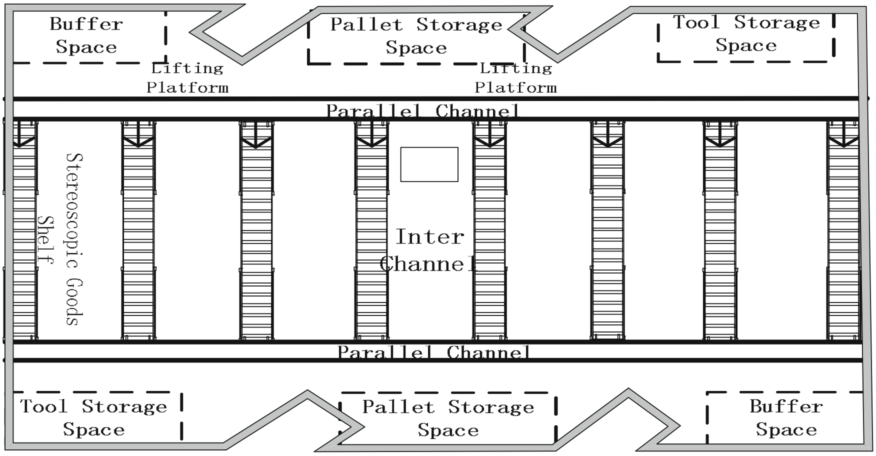


Fig. 94.1 Company Z storehouse layout

(1) There is no independent picking up space in the storehouse. Goods which are removed off shelves stack on the nearest passageway, which causes congestion. Forklifts can't put inventory goods on shelves in time, which causes the overflow of the buffer space and leads to additional work such as transferring storehouse. Therefore, storehouse activity efficiency is very low.
(2) Tools are misplaced. Tools are left about after used, which causes tool damage.
(3) The storage of each batch of goods. Because the paper storehouse and laundry detergent storehouse are far away from the substitute storehouse, increases the logistics cost.
(4) Some goods need the secondary package before delivery, but the secondary package workshop is far away from the paper storehouse and laundry detergent storehouse, which increases the handling and human cost.
(5) The goods for sorting store in chaos, leading to inventory error. The team leader spends most of the time doing the inspection work every day.

94.2 The Data Collection

According to the classification of Company Z's goods, we reach the goods type table (see Table 94.1). Company Z's monthly average amount of inbound, outbound and distribution (see Table 94.2).

Table 94.1 The goods category table of company Z storehouse

Serial number	Product name	Nature of product	Storehouse
1	Pampers	Solidity	Paper storehouse
2	Whisper	Solidity	
3	Naturella	Solidity	
4	Soap (Safeguard, Olay)	Solidity	Kkincare and washing storehouse
5	Shampoo (5 series)	Liquid	
6	Toothpaste	Solidity	
7	Toothbrush	Solidity	
8	Detergent powder (Tide, Ariel)	Solidity	Detergent storehouse
9	Laundry detergent (Tide, Ariel)	Liquid	
10	Skincare (Olay, SK II)	Liquid	Strong room (storehouse for goods to-be-transferred)
11	Gillette series	Solidity	
12	Pringles	Solidity	
13	Duracell	Solidity	
14	Lang liquor	Liquid	Lang liquor storehouse

Table 94.2 Goods Q quantity table

Storehouse name	Monthly average shipment	Characteristics of distribution
Detergent storehouse	420,000 pieces	Parallel distribution (equal monthly)
Paper storehouse	380,000 pieces	Quadratic distribution
Skincare and washing storehouse	580,000 pieces	Quadratic distribution
Lang liquor storehouse	50,000 pieces	Parallel distribution
Strong room	110,000 pieces	Parallel distribution

94.3 Optimization Process of Company Z Storehouse Center Layout

Using clear, logical SLP (system layout planning) method, we optimize the storage center layout of Company Z.

(1) The department division and logistics flow chart

Name list of activity department division (see Table 94.3).

According to the process flow of all kinds of products in the storage center, we draw the logistics process table of the various products (see Table 94.4), in which A is the entrance, and B is the exit.

Table 94.3 Code table of each activity space

Serial number	Name of activity unit
1	Office building
2	Dispatching room
3	The second package workshop
4	Receiving platform
5	Stocking buffer space
6a	Detergent storehouse
6b	Paper storehouse
6c	Skincare and washing storehouse
6d	Lang liquor storehouse
6e	Strong room
7	Appliance storage space
8	Sorting activity space
9	Shipping buffer space
10	Shipping platform

Table 94.4 Logistics process table

Product type	Logistics process
Detergent	A→4 →5→6a→8→9→10→B
Paper	A→4→5→6b→8→9→10→B
Skincare and washing products	A→4→5→6c→8→9→10→B
Lang liquor	A→4→5→6d→8 9→10→B
Valuables	A→4→5→6e→8→9→10→B

(2) P-Q analysis

According to the principle of SLP, importing quantity of the goods (see Table 94.2), it concludes the results of the analysis of the products and production (P-Q) (see Table 94.5).

(3) Logistics strength analysis

Each type of goods is packed into packages. Forklifts deliver all goods in the storehouse Z. When there are multiple products going through the same starting and ending departments, the different products going through the starting and ending units are accumulated, and the monthly transportation volume is summarized, then it concludes the transportation volume from-to table (see Table 94.6).

By SLP method, the strength of logistics is divided into five grades A, E, I, O, U. A, E, I, O, U logistics route rate and the logistic volume rate is as follow (see Table 94.7), thus related logistics table of different activity space is concluded (see Table 94.8). According to Strength grade proportion and logistics related table of different activity space, design the activity units relationship table. (see Fig. 94.2).

Table 94.5 Product P-Q analysis result table

Product type	Difficulty level of handle	Quantity (ten thousand pieces)
	α	Monthly average
Detergent	4	42
Paper	3	38
Skincare and washing products	2	58
Lang liquor	1	5
Valuables	1	19

Table 94.6 Transportation volume table from place-to place (Unit: ten thousand pieces)

Number	A	4	5	6a	6b	6c	6d	6e	8	9	10	B
A	–	162	–	–	–	–	–	–	–	–	–	–
4	–	–	162	–	–	–	–	–	–	–	–	–
5	–	–	–	42	38	58	5	19		–	–	–
6a	–	–	–	–	–	–		–	42	–	–	–
6b	–	–	–	–	–	–	–	–	38	–	–	–
6c	–	–	–	–	–	–	–	–	58	–	–	–
6d	–	–	–	–	–	–	–	–	5	–	–	–
6e	–	–	–	–	–	–	–	–	19	–	–	–
8	–	–	–	–	–	–	–	–	–	162	–	–
9	–	–	–	–	–	–	–	–	–	–	162	–
10	–	–	–	–	–	–	–	–	–	–	–	162
B	–	–	–	–	–	–	–	–	–	–	–	–

Table 94.7 Logistics strength grade partition table

Logistics strength grade	Symbol	Logistics route percentage (%)	Logistics volume handling percentage (%)
Absolutely necessary	A	10	40
Especially important	E	20	30
Important	I	30	20
Ordinary important	O	40	10
Unimportant	U		

(4) Comprehensive relationship between the activity units

Considering relationship between logistics and non-logistics, solve the close degree level of comprehensive relationship (see Table 94.4).

(5) Activity units relationship diagram

According to the sheet size, select the unit length of the distance, and regulate: the distance between two work units whose relationship close grades are classified as A is one length unit, E is two length units, and so on.

Table 94.8 Rrelated logistics table of different activity space

Work unit number	4	5	6a	6b	6c	6d	6e	8	9	10
4	–	162 A	–	–	–	–	–	–	–	–
5	–	–	42 E	38 E	58 E	5 O	19 I	–	–	–
6a	–	–	–	–	–	–	–	42 E	–	–
6b	–	–	–	–	–	–	–	38 E	–	–
6c	–	–	–	–	–	–	–	58 E	–	–
6d	–	–	–	–	–	–	–	5 O	–	–
6e	–	–	–	–	–	–	–	19 I	–	–
8	–	–	–	–	–	–	–	–	162 A	–
9	–	–	–	–	–	–	–	–	–	162 A
10	–	–	–	–	–	–	–	–	–	–

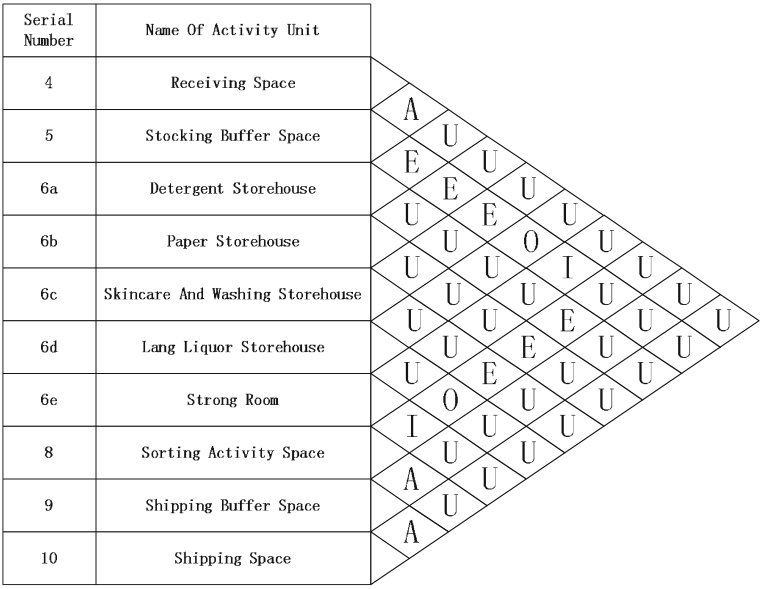


Fig. 94.2 Activity space logistics intensity correlation

By Table 94.8, conclude the logistics intensity contrast diagram (see Fig. 94.3).

According to the comprehensive relationship level, i.e., A, E, I, O, U level sequence, successively determine the activity unit arrangement of different levels, and the activity units of the same level are arranged according to the high and low order of the comprehensive close degree score (Fig. 94.4).

Final correlation diagram of positions of the activity units is as follow (see Fig. 94.5).

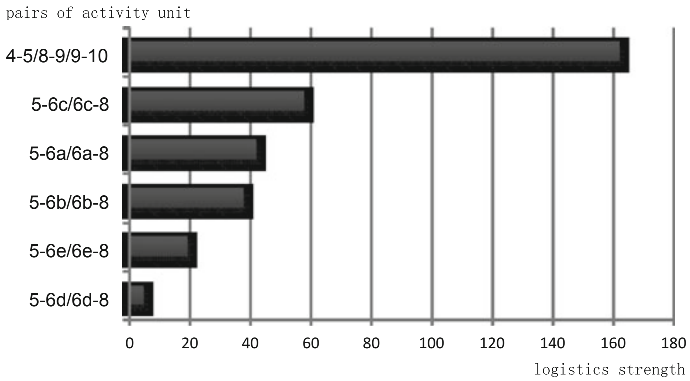


Fig. 94.3 Logistics intensity contrast figure

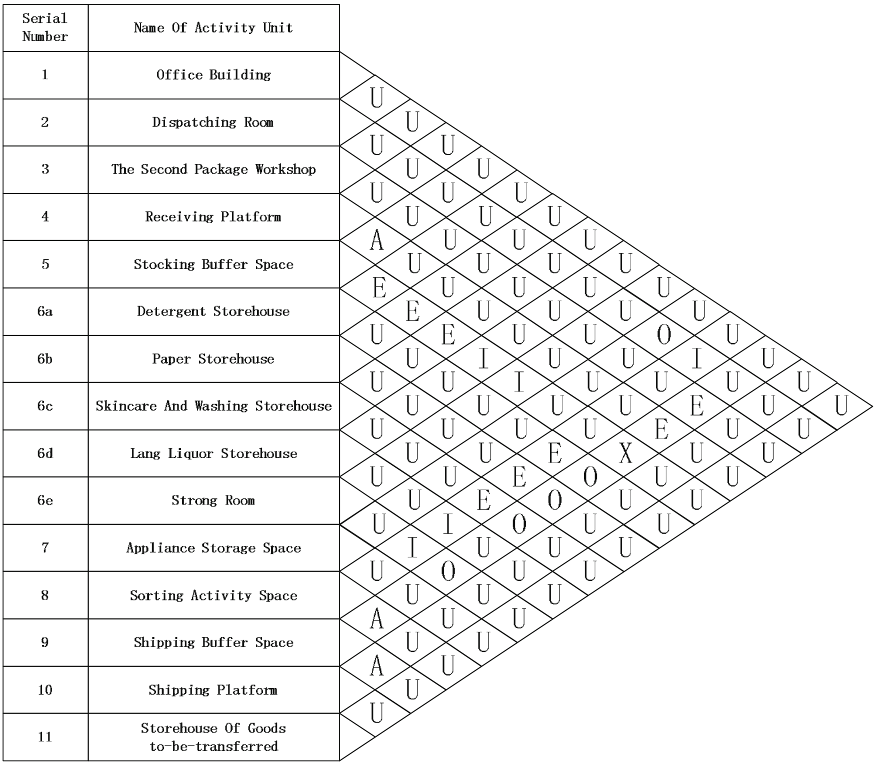


Fig. 94.4 Activity units comprehensive relationship

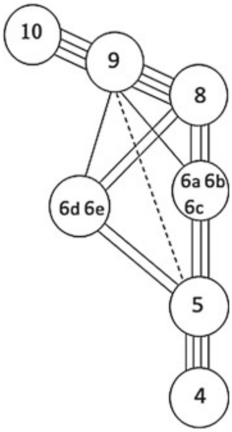


Fig. 94.5 The activity unit position relevant

(6) The layout scheme

Consider correction factors: material handling, factory building structure, road, utility piping layout, greening, and environment.

Actual restrictions: the factory space, the transformation cost, the existing factory building restrictions, policies and regulations, etc.

Combined with correction factors and the actual restrictions, get the following storehouse layout (see Figs. 94.6, 94.7 and 94.8).

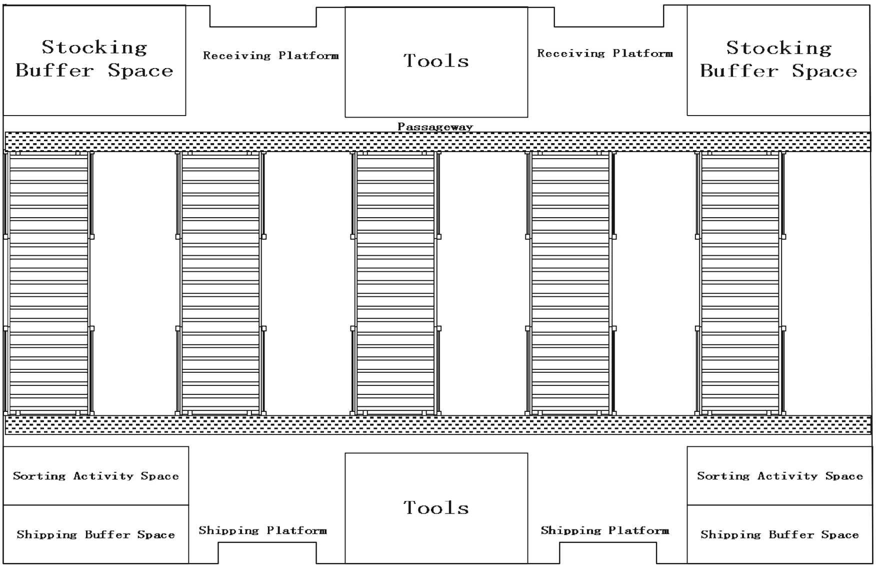


Fig. 94.6 Storehouse layout scheme one

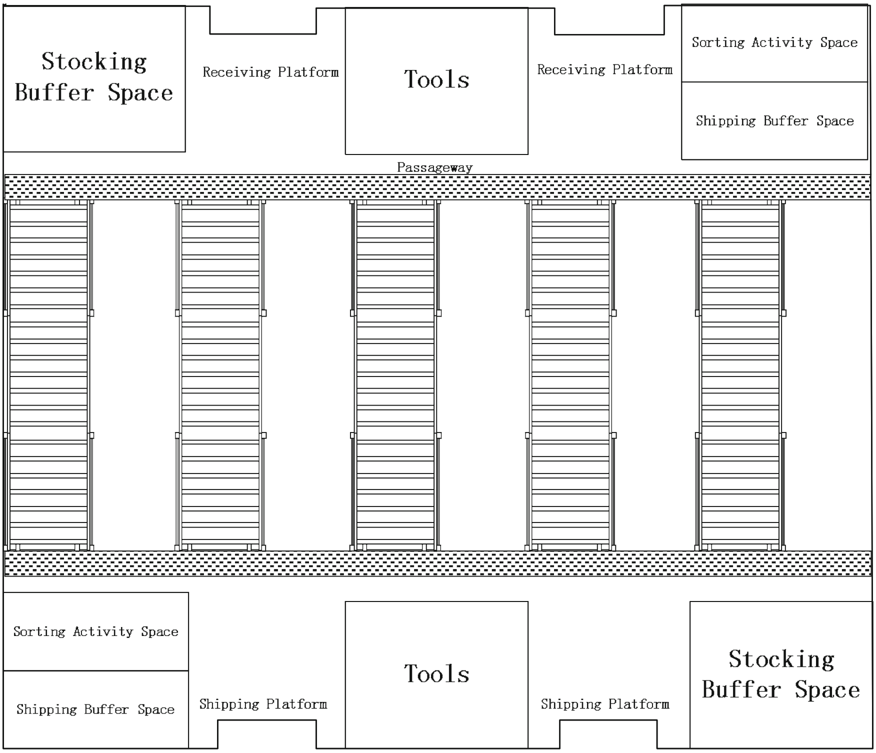


Fig. 94.7 Storehouse layout scheme two

(7) Project evaluation

With SLP method, draw the above three storehouse optimization layout schemes. In order to do the comparison between schemes better, select factors which affect the storehouse activity and management, and use the analytic hierarchy process (AHP), do the comparison between each scheme and select the better one.

Defining the scale between elements (see Table 94.9), we use square root method to calculate the normalized relative importance degree of each factor relative to the corresponding factor of the upper layer.

$$W_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}, \tag{94.1}$$

$$W_i^0 = \frac{W_i}{\sum_i W_i} i = 1, 2, \ldots, n. \tag{94.2}$$

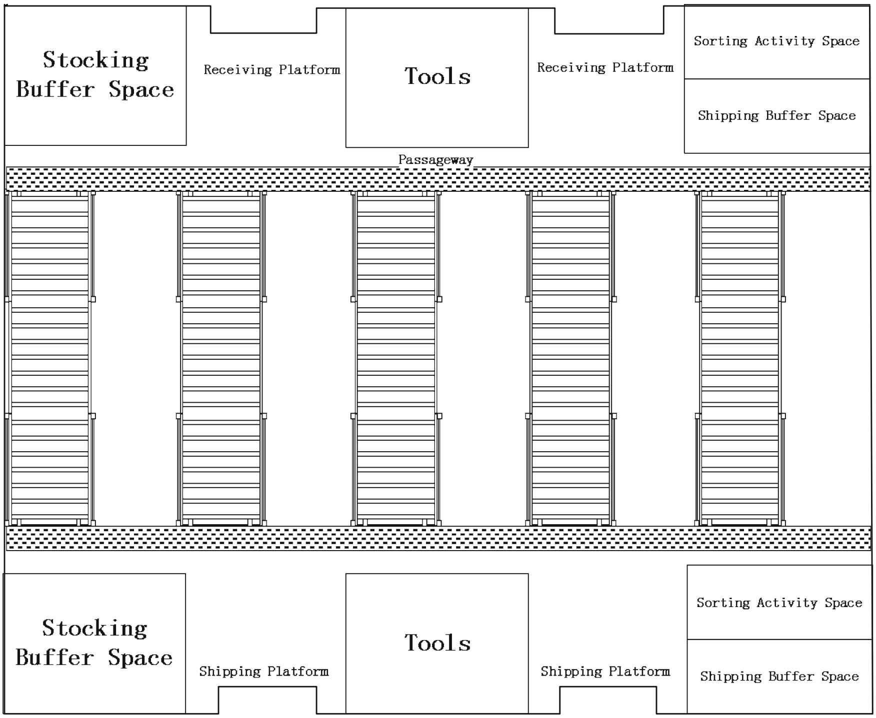


Fig. 94.8 Storehouse layout scheme three

Table 94.9 Judgment matrix scale definition

Scale	Implication
1	Comparing two elements, the importance is the same
3	Comparing two elements, the former is more important
5	Comparing two elements, the former is obviously more important
7	Comparing two elements, the former is especially important
9	Comparing two elements, the former is absolutely important
2, 4, 6, 8	Median of above adjacent judgments
Count backwards	Comparing two elements, the latter is more important

Consistency Test method: Consistency index

$$C.I. = \frac{\lambda_{\max} - n}{n - 1}. \tag{94.3}$$

$\lambda_{\max} \approx \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{W_i} = \frac{1}{n}\sum_{i=1}^{n}\frac{\sum_{j=1}^{n} a_{ij}W_j}{W_i}$, AW_i stands for the ith component of AW.

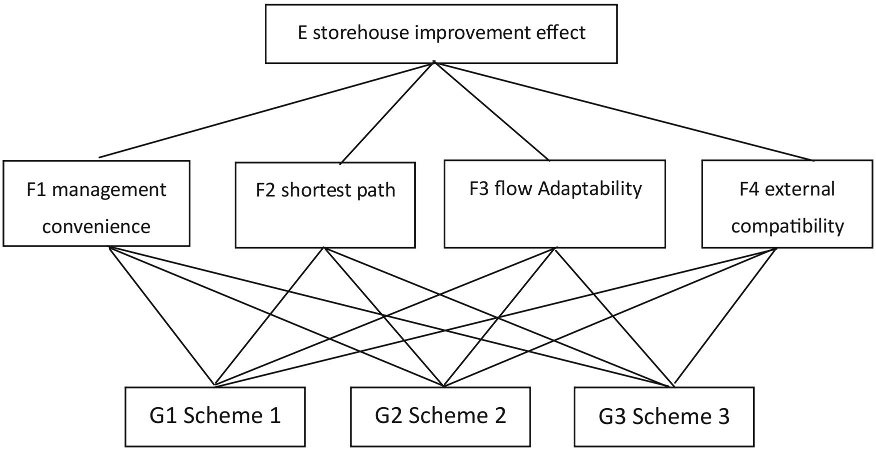


Fig. 94.9 The storehouse improvement evaluation structure model

Table 94.10 Index class one weight distribution table

E	F1	F2	F3	F4	W_i	W_i^0	λ_{mi}	
F1	1	5	3	7	3.201	0.583	4.078	
F2	2016/1/5	1900/1/1	2016/1/2	2	0.707	0.129	3.858	$\lambda_{\max} = 4.0215$
F3	2016/1/3	1900/1/2	1900/1/1	3	1.189	0.217	4.078	$C.I. = 0.0072 < 0.1$
F4	2016/1/7	2016/1/2	2016/1/3	1	0.393	0.071	4.072	

To meet the requirements of storehouse activity and storehouse management, choose management convenience, path, the adaptation of process, the accessibility of external coordination as evaluation factors. These factors form the evaluation structure model. (see Fig. 94.9).

The Table 94.10 shows: management convenience, shortest path, and process adaptability and external coordination factors respectively account for 0.583, 0.129, 0.217, 0.071 of storehouse optimization index weight. Ci < 0.1. Consistency check passed. Table 94.11 shows: plan one, two, three respectively accounts for 0.648, 0.230, 0.122 of management convenience indices weight. Ci < 0.1. Consistency check passed.

The Table 94.12 shows: plan 1, 2, 3 respectively accounts for 0.637, 0.258, 0.105 of the shortest path index weights. Ci < 0.1. Consistency check passed.

The Table 94.13 shows: plan 1, 2, 3 respectively accounts for 0.075, 0.592, 0.333 of the process adaption index weights. Ci < 0.1. Consistency check passed.

The Table 94.14 shows: plan 1, 2, 3 respectively accounts for 0.600, 0.200, 0.200 of the external coordination index weights. Ci < 0.1. Consistency check passed.

Table 94.11 Management convenience weights allocation chart of all the schemes

F1	G1	G2	G3	W_i	W_i^0	λ_{mi}	
G1	1	3	5	2.466	0.648	3.004	$\lambda_{\max} = 3.004$
G2	2016/1/3	1900/1/1	2	0.874	0.23	3.002	$C.I. = 0.002 < 0.1$
G3	2016/1/5	2016/1/2	1	0.464	0.122	3.005	

Table 94.12 Shortest path weights allocation chart of the program

F2	G1	G2	G3	W_i	W_i^0	λ_{mi}	
G1	1	3	5	2.466	0.637	3.04	$\lambda_{\max} = 3.039$
G2	2016/1/3	1900/1/1	3	1	0.258	3.04	$C.I. = 0.02 < 0.1$
G3	2016/1/5	2016/1/3	1	0.406	0.105	3.036	

Table 94.13 The process to adapt to the weights allocation chart of the program

F3	G1	G2	G3	W_i	W_i^0	λ_{mi}	
G1	1	2016/1/7	2016/1/5	0.306	0.075	3.012	$\lambda_{\max} = 3.014$
G2	7	1900/1/1	1900/1/2	2.41	0.592	3.015	$C.I. = 0.007 < 0.1$
G3	5	2016/1/2	1900/1/1	1.357	0.333	3.016	

Table 94.14 External coordination scheme weights allocation table

F4	G1	G2	G3	W_i	W_i^0	λ_{mi}	
G1	1	3	3	2.08	0.6	2.999	$\lambda_{\max} = 3$
G2	2016/1/3	1	1	0.693	0.2	3	$C.I.=0 < 0.1$
G3	2016/1/3	1	1	0.693	0.2	3	

Table 94.15 shows: plan one, two and three respectively accounts for 0.519, 0.310, 0.171 of relative weight in improvement effects on storehouse layout scheme. Known by the evaluation result, plan one is better than scheme 2, scheme 2 is better than scheme 3, therefore, choose plan one to improve the layout scheme.

Table 94.15 External coordination scheme weights allocation table

Fi	F1	F2	F3	F4	$C_i = \sum_{i=1}^{3} b_i c_j$
	0.583	0.129	0.217	0.071	
G1	0.648	0.637	0.075	0.6	0.519
G2	0.23	0.258	0.592	0.2	0.31
G3	0.122	0.105	0.333	0.2	0.171

To sum up, after the evaluation analysis of factory general layout and storehouse layout schemes, come to the conclusion that the result of comprehensive evaluation of the combination of general layout and storehouse layout is as follows:

The best layout is the combination of general layout plan 2 and storehouse layout plan 1.

Chapter 95
Production System Performance Improvement by Assembly Line-*seru* Conversion

Luming Shao, Zhe Zhang and Yong Yin

Abstract *Seru*, as a new effective and flexible production system, has been successfully proved in practice and received more and more attention from academic communities. However, line-*seru* conversion is an interesting but difficult problem because the product demand is uncertain and worker's skill levels are different. In this paper, we propose a multi-objective model to describe line-*seru* problem with one product type but many orders for minimizing the total flow time and the total labor cost. Taking line-*seru* conversion problem in the electronics industries as an example, how much time and cost can be reduced and how many efficiencies can be improved by line-*seru* conversion are analyzed. According to the solutions of the proposed multi-objective model, *seru* has a great performance and different *seru* combinations can bring unequal reduction of time and cost.

Keywords *Seru* · Conveyor assembly line · Line-*seru* conversion · Multi-objective

95.1 Introduction

In the volatile and uncertain market, such as electronics industry, the business is in a rapidly changing environment because of its shorter product life cycles, more unpredictable product types, and the variable production volumes with the fast innovation technology [9]. There are two main aspects of demand changes: product variety and

L. Shao · Z. Zhang (✉)
School Economics and Management, Nanjing University of Science and Technology, Nanjing 210094, People's Republic of China
e-mail: zhangzhe@njust.edu.cn

Y. Yin
Graduate School of Business, Doshisha University, Karasuma-imadegawa, Kamigyo-ku, Kyoto 602-8580, Japan

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_95

product volume [8]. To cope with volatile demand, many electronic giants attempt to apply Toyota Production System (TPS) to satisfy fluctuations in customers demand but failed, and the economies of scale and shorter cycle time brought by mass production are disappearing. The efficiency and low cost of the conveyor assembly line will greatly decrease when met with volatile demands [1]. Hence, traditional TPS system applied in conveyor assembly line could not satisfy the volatile customers demand because of the fast updates of products. In this situation, to produce more variety, flexible volume and high-value-added products, Sony invited an expert, Hitoshi Yamada, to solve this problem after failing to test the new manufacturing approaches including TPS and one-person production organization [12].

In 1992, several short lines replaced the long assembly conveyor line to produce the entire product in Sony [12], and that made a big success. In 1994, Kon Tatsuyoshi, a former staff of Sony, first called the term "*seru seisan*" for such an innovation of the production management system [11]. In Japan, "*seru Seisan*" is really popular in some manufacturing industries as the most powerful and practical way under the volatile environment [7]. In fact, *seru* has many advantages: it can reduce labor cost, lead time, setup time, work-in-process (WIP) inventories, semi-finished and finished product inventories, equipment cost and space. In addition, *seru* also increases profits, and improves product quality and motivates workers in a great way [10].

Seru is an assembly organization, which is consisted of required equipment and workers, to produce one or more products (only one product type in most cases). A *seru* has three characteristics: firstly, Kanketsu, which means all tasks are completed in a *seru*; Secondly, Majime, which means all required resources are placed close to reduce unnecessary movement; thirdly, Jiritsu, which means self-management and learning organization [12]. What's more, there are three types of *seru*: Divisional *seru*, Rotating *seru* and Yatai [5]. Many famous Japanese companies such as Sony, Canon, Panasonic, NEC, Fujtsu, Sharp and Sanyo have adopted *seru* and not only acquire economic benefits but also environment benefits.

As *seru* has continuously achieved big success in not only Japan but also Korea and China, more and more attention have paid to performance indicators of *seru*. Several papers analyse the performance of line-*seru* conversion affected by operational factors. Johnson [2] adopted a previous theory to illustrate why assembly *serus* have a better performance than traditional conveyor assemble line. He studied the simulation models to observe the marginal impact when the operational factors are changed in this conversion. Kaku et al. [3] constructed a theoretical model considering human factors in the conversion. They argued the cross-trained workers should be the key role in the conversion. By using human memory ability they analysed the cross-training of workers quantitatively and found that information support system is benefit for improving the cross-training effect. Yu et al. [13] proposed a 64-array experiment and used three non-dominated solutions to find operational factors or interactions between them which may improve the performance. They suggested several insights about the formation of assembly *serus* and load *serus* based on the experimental results.

For the methods to achieve better line-*seru* performance, many researchers use a multi-objective model to optimize two line-*seru* performances: the total throughput time and the total labor hour. Kaku et al. [4] researched 24 cases about line-*seru* conversion and concluded that this conversion can greatly adapt multi-item small-sized products. They proposed a linear weight method to solve the multi-objective problem and determine the most profitable layout of cells and workers in it. Yu et al. [15] constructed a multi-objective model for two goals and adopted an improved exact algorithm by transferring the multi-objective optimization into the single objective optimization. Liu et al. [6] proposed a three-stage heuristic algorithm with nine steps to solve this optimal problem and took several computational cases to validate the performances of model and algorithm by MATLAB programming. Yu et al. [14] proved that the line-*seru* conversion problem is NP-hard and the non-dominated or pareto-optimal front of the multi-objective problem is non-covex. They developed a non-dominated sorting genetic algorithm which can solve large size problems in a reasonable time to solve multi-objective problem and used several numerical examples to verify the reliability. However, the papers mentioned above just consider time as the optimal objective and suppose that orders can not be split in general. In this paper, the labor cost is introduced as optimal objective and will be calculated with two levels of worker skill, and we also plan to find whether the efficiency increase or not if split the orders. Additionally, the most appropriate quantity of each *seru* for the best balance will be pointed out.

This paper is aim to show *seru* is more suitable for the electronics industry by comparing the efficiency of *seru* and the conveyor line. The paper is organized as follows. In Sect. 95.2, we will present the problem description, including the brief explanation and introduction of variables. Then, the multi-objective model and assumptions as well as notation will be given in detail. In Sect. 95.3, the efficiency of *seru* and the conveyor line will be shown under a numerical example in electronics industry. Furthermore, in the Sect. 95.4, we will make a comparison between these two product systems in serval aspects to illustrate the advantages of line-*seru* conversion. The conclusion and future research will be put forward in Sect. 95.5.

95.2 Problem Statement

The problem considered in this paper is from a practical production problem of low efficiency and flexibility in some assembly areas. As conveyor assembly line has been widely accepted, it has been found many disadvantages increasingly. For example, it should continue working to keep high efficiency and low cost; workers may have much idle time and so on. Therefore, in electronic assembly area, *seru* has been paid more and more attention because of better performance in some aspects. *Seru* is a small production assembly organization, it can be constructed, dismantled, and reconstructed quickly. However, when we apply it in practical production, we may face how to design *seru* and assign workers in it for the best profit rate. In this paper, we introduce a multi-objective model to describe this line-*seru* conversion problem and propose a solution to solve the numerical example.

95.3 Modelling

As mentioned above, there are three types of *seru*: divisional *seru*, rotating *seru* and yatai, and Yin et al. [12] introduced three types in detail: Divisional *seru* is a short assembly line and composed by several partially cross-trained workers responsible for several tasks. Rotating *seru* is commonly a U-shaped assembly line which is equipped fixed stations for cross-trained workers walking from one to another to perform all required tasks of a product. *Yatai* is a special *seru* as there is only one worker in it to produce required products. In this paper, rotating *seru* and *yatai* are considered and divisional *seru* is a further issue to discuss. Assumption is that one product type is produced which has different known orders. Two types of assembly system are shown in the Fig. 95.1, including a pure *seru* system and a pure conveyor line system. In traditional conveyor assembly line, products are produced constantly in line. But when it comes to *seru*, we may face how to design *serus* and assign workers in it for the best profit rate. Hence, this paper considers two objectives: to minimize the total flow time and the total labor cost. And in this section, a multi-objective mathematical model of line-*seru* will be developed.

95.3.1 Problem Assumptions

Following assumptions are considered in line-*seru* to construct the multi-objective model:

- The orders of product are known and constant;
- The number of assembly tasks is the same to two types of assembly system;
- If the assembly system is a conveyor line, just one conveyor line is considered;
- The number of workers is same with the number of tasks on the conveyor line;
- A worker only does one assembly task in conveyor line;
- The number of workers in each *seru* may be different but limited;

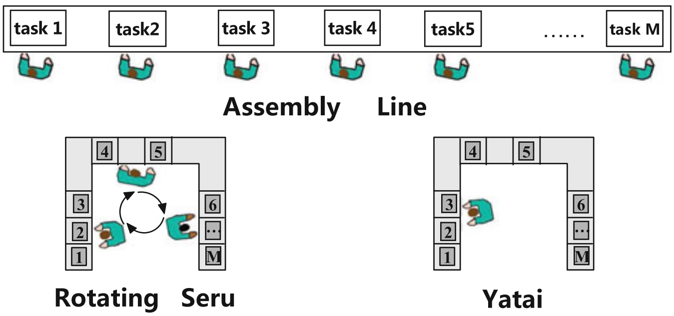


Fig. 95.1 Two types of assembly system

- A worker assigned in a *seru* can operate all the tasks required;
- The setup time between two batches is zero.

95.3.2 Notation

Here, the assembly problem based on one product with different product orders is considered, in which workers have been assigned to the conveyor line or *seru* already. Following notation are used in the multi-objective model.

Indices

i: Index of set workers ($i = 1, 2, \ldots, W$).
j: Index of set production units ($j = 1, 2, \ldots, J$).
m: Index of set product orders ($m = 1, 2, \ldots, M$).
k: Index of set the sequence of product orders in a *seru* ($k = 1, 2, \ldots, M$).

Parameters

B_{mn}: Size of batch n in product order m ($n = 1, 2, \ldots, N$).
TP: Total time of all processes.
η_i: Upper bound on the number of tasks for worker i in a cell. If a worker is assigned to a number of tasks over than it, the task time will become longer than ever.
C_i: Coefficient of variation of worker i's increased task time after the line-*seru* conversion as he or she is from a specialist to a completely cross-trained worker.
Y_i: The cost of worker i per second.
ε_i: Worker i's coefficient of influencing level of doing multiple assembly tasks.
β_i: Skill level of worker i for each task of product.

Decision variables

X_{ij} : If worker is assigned to cell, $X_{ij} = 1$, otherwise, $X_{ij} = 0$.
Z_{mnjk}: If batch of product order is assigned to cell in sequence, $Z_{mnjk} = 1$, otherwise, $Z_{mnjk} = 1$. In addition, if $k = 0$, Z_{mnjk}=0.

Variables

FS_{mn}: Flow time of product batch n of order m in a *seru*.
FSB_{mn}: Begin time of product batch n of order m in a *seru*.
T_{bp}: Process time of bottleneck.

95.3.3 Formulation

Here is an manufacturing assembly problem: there exists a traditional belt conveyor assembly line with various assembly stations, and workers are assigned at each station according to a traditional job design method but they have had abilities to finish all tasks which are easy to learn. Meanwhile, there are also some *serus* with the same tasks. The assembly plan with one type product has M orders, W workers have been assigned in two product systems already. In addition, the orders are produced according to an First come first service (FCFS) principle.

At first, each worker is specialized with original work in conveyor assembly line, and need training to become as a cross-trained worker. If tasks assigned to a worker are beyond η_i, the flow time will be longer as the worker is not familiar with too many tasks. The details are given:

$$C_i = \begin{cases} 1 + \varepsilon_i \times (W - \eta_i), \ W \geq \eta_i, \\ 1, \qquad\qquad\qquad\qquad \text{otherwise.} \end{cases} \tag{95.1}$$

Subsequently, the flow time of a product varies with workers' skill levels. $TP \times C_i \times \beta_i$ means the time for worker i to finish one product. B_{mn} means the size of batch n in order m. Hence, the flow time can be represented as follows:

$$FS_{mn} = \frac{B_{mn} \times \max(T_P \times C_i \times \beta_i)}{\sum_{i=1}^{W} \sum_{j=1}^{J} \sum_{k=1}^{M} X_{ij} \times Z_{mnjk}}. \tag{95.2}$$

Then, since each worker has different skill levels, so according to β_i, all workers are classified in two classes. The cost of different workers is following:

$$Y_i = \begin{cases} a, \text{ if } \ \beta_i \geq 1, \\ b, \text{ otherwise.} \end{cases} \tag{95.3}$$

Finally, because there is no waiting time and setup time, the start time of each batch is the sum of flow time for all preview product batches assembled in the same *seru*.

$$\mathrm{FSB}_{mn} = \sum_{s=1}^{M-1} \sum_{n=1}^{N} \sum_{j=1}^{J} \sum_{k=1}^{M} FS_{mn} \times Z_{mnjk} \times Z_{snj(k-1)}. \tag{95.4}$$

(1) Total Flow Time Minimization Objective

The total flow time is depend on the finish time of the last product batch, so we can calculate the finish time of all orders in the following function:

$$\mathrm{TFT} = \min\{\max_{mn}(FSB_{mn} + FS_{mn})\}, \tag{95.5}$$

where $FS_{mn} + FSB_{mn}$ is the finish time of batch n in order m.

Besides, when workers are assigned into different *serus*, we should make sure that all workers are assigned to assemble the required products. Thus,

$$\sum_{j=1}^{J}\sum_{i=1}^{W} X_{ij} = W, \forall(i,j). \tag{95.6}$$

About the worker assignment rule, each worker should be assigned to one and only one *seru*. That means workers are not allow to help other *serus* when needed, so

$$\sum_{j=1}^{J} X_{ij} = 1, \forall i. \tag{95.7}$$

If there is no worker in this *seru*, we cannot assign assembly task to it, i.e.,

$$\sum_{m=1}^{M}\sum_{k=1}^{M} Z_{mnjk} = 0, \left\{\forall j \mid \sum_{i=1}^{W} X_{ij} = 0\right\}. \tag{95.8}$$

In addition, the product orders must be assigned sequentially, and

$$\sum_{j=1}^{J}\sum_{k=1}^{M} Z_{mnjk} \le \sum_{j'=1}^{J}\sum_{k'=1}^{M} Z_{(m-1)nj'k'}, m = 2, \ldots, M. \tag{95.9}$$

(2) Total Labor Cost Minimization Objective

The total labor cost is the sum of the cost of each worker. As mentioned above, we can know how much time each worker spends on assembling, so the objective function is:

$$\mathrm{TLC} = \min \sum_{m=1}^{M}\sum_{n=1}^{N}\sum_{i=1}^{W}\left(\sum_{j=1}^{J}\sum_{k=1}^{M} FS_{mn} \times X_{ij} \times Z_{mnjk} \times Y_i\right). \tag{95.10}$$

Therefore, combining the Eqs. (95.5)–(95.10), we have:

$$\begin{aligned}
&\mathrm{TFT} = \min\{\max_{mn}(\mathrm{FSB}_{mn} + FS_{mn})\}\\
&\mathrm{TLC} = \min \sum_{m=1}^{M} \textstyle\sum_{n=1}^{N} \sum_{i=1}^{W} (\sum_{j=1}^{J} \sum_{k=1}^{M} FS_{mn} \times X_{ij} \times Z_{mnjk} \times Y_i)\\
&s.t. \begin{cases}
\sum_{j=1}^{J} \sum_{i=1}^{W} X_{ij} = W, & \forall(i,j)\\
\sum_{j=1}^{J} X_{ij} = 1, & \forall i\\
\sum_{m=1}^{M} \sum_{k=1}^{M} Z_{mjk} = 0, & \{\forall j \mid \sum_{i=1}^{W} X_{ij} = 0\}\\
\sum_{j=1}^{J} \sum_{k=1}^{M} Z_{mjk} \le \sum_{j'=1}^{J} \sum_{k'=1}^{M} Z_{(m-1)j'k'}, & m = 2, \ldots, M.
\end{cases}
\end{aligned} \tag{95.11}$$

95.4 Solution Method

From the descriptions of TLC and TFT, all the parameters are involved in minimization objective and there are many satisfied solutions which are hard to enumerated, as the proposed multi-objective model have been proved as NP-hard. Therefore, in this paper, we try to compare two production systems by the satisfying solutions in the same situation. The orders and workers are known, what we need to do is to find how many *serus* are formed and how to assign workers in it for the objectives. FCFS principle are applied in *seru* design, and supposed that orders can not be split at first. The procedure should be processed as follows:

Step 1. J *serus* should be set up and workers are allocated in them on average.
Step 2. Find the worker who has the longest flow time in each *seru*, thus these workers are bottlenecks of each *seru*, and bottlenecks are arranged in the order of smallest to largest to *seru* 1, *seru* 2, ..., *serus* J.
Step 3. At first, order 1 are arranged to *seru* 1, order 2 are arranged to *seru* 2 and so on. Thus, calculating the finish time of each order.
Step 4. Then, according to FCFS principle, the next order will be arranged to the *seru* which has least flow time and the order after next are arranged to the *seru* which has the second least flow time. Repeat this process, until all orders are allocated.
Step 5. The slowest finish time is as the TFT, and TLC is the sum of each *seru*'s labor cost.

On the other hand, considering orders split, how to separate orders to get an optimal results is the most challenging problem. If all *serus* finish production tasks at the same time, the idle time will be less. Therefore, the most suitable task arrangement for each *seru* should be calculated. Weighted average is accepted for the best balance due to different workers' skill levels. The procedure is:

Step 1. J *serus* should be set up and workers are allocated in them.
Step 2. Find the worker who has the longest flow time in each *seru*. These workers are bottleneck of each *seru*, and bottlenecks are arranged in the order of smallest to largest to *seru* 1, *seru* 2, ..., *serus* J. Recording the workers as $w_1, w_2, \ldots, w_J$.
Step 3. Calculating the best allocation for the best balance. $\frac{1}{\beta_{w_j} \times C_{w_j}}$ as the weight and the sum of orders is 401, correspondingly, we can get the appropriate tasks of workers. In a *seru*, $\frac{401}{\sum_{j=1}^{J} \frac{1}{\beta_{w_j} \times C_{w_j}}} \times \frac{1}{\beta_j \times C_j}$ is one best allocation of *seru* j.
Step 4. Using FCFS principle to arrange tasks and satisfy each *seru*'s best allocation until all orders are finished. If the quantity of order is less than the best allocation, the order can be allocated to this *seru*. But if in contrast, the order should be split to satisfy the best allocation for best balance.
Step 5. The slowest finish time is as the TFT, and TLC is the sum of each *seru*'s labor cost.

95.5 Application

95.5.1 Data

Here, considering line-*seru* problem in assembly process of mobile phone, we will analyze how much time and cost can be reduced and how many efficiencies can be improved by line-*seru* conversion. Assembly process of mobile phone includes 12 workers and 8 orders, and the related data is in Tables 95.1 and 95.2, respectively.

95.5.2 Numerical Examples

Since the solution method have been given in the above section, so we can compare two production systems as follows.

(1) Conveyor Assembly Line Production System

There are 8 orders and the quantity of required products is 401 in total. In the conveyor assembly line, 12 processes are involved and the bottleneck is process k. We can calculate the finish time and labor cost as:

$$\mathrm{TFT} = TP + \sum_{m=1}^{8} \times T_{bp} = 10179;\ \mathrm{TLC} = \mathrm{TFT} \times 12 \times b = 122148b.$$

Table 95.1 Process time lists

Tasks	Processing time (units: s)	Capacity (units: day)
A: Prepare materials	12	2400
B: Primary assembly (I)	12	2400
C: Primary assembly (II)	14	2057
D: Battery assembly	7	4114
E: Package assembly	17	1694
F: Appearance check	12	2400
G: Phasing test	20	1440
H: Pre-Alert check	21	1371
I: Camera test	14	2057
J: LAD test	13	2215
K: CIT test	25	1152
L: QC	12	2400

Table 95.2 The parameters of the example [13]

Parameters	Workers											
	1	2	3	4	5	6	7	8	9	10	11	12
Skill levels (β_i)	1.02	1.09	0.96	0.94	0.96	1.03	0.98	1.1	1.04	1.07	0.99	1.04
Coefficient of skill levels (ε_i)	0.012	0.006	0.007	0.009	0.008	0.014	0.016	0.013	0.012	0.005	0.013	0.022
Factor values	$\varepsilon_i \sim N(0.01, 0.005)$, $TP = 179$, $T_{bp} = 25$, $\eta_j = 10$											
Order size	order 1 = 55, order 2 = 48, order 3 = 54, order 4 = 49, order 5 = 47, order 6 = 51, order 7 = 45, order 8 = 52											

Table 95.3 Several *serus* formations

Serus number	*Serus* formation
1	{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12}
2	{{1, 2, 3, 4, 5, 6}, {7, 8, 9, 10, 11, 12}}
3	{{1, 2, 3, 4}, {5, 6, 7, 8}, {9, 10, 11, 12}}
4	{{1, 2, 3}, {4, 5, 6}, {7, 8, 9}, {10, 11, 12}}

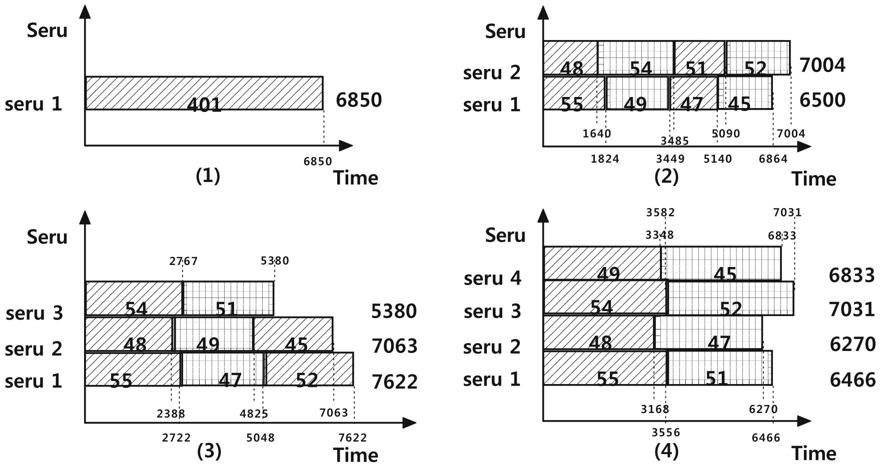


Fig. 95.2 Arrangements of orders (1)

(2) *Seru* Production System

① Orders cannot be split

Supposed that orders cannot be split so that there are 8 *serus* at most, thus we design four *serus* shown in the Table 95.3, where {1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12} means a rotating *seru* with 12 workers in it.

According to FCFS principle, the orders are arranged to appropriate *serus* as shown in the Fig. 95.2.

In Fig. 95.2 (1), there is only one *seru*, so all orders are arranged to it and calculation is simple. The bottleneck is worker 8 and the flow time is 205, TFT is $401 \times 205/12 = 6850$. About TLC, there 5 workers' skill levels less than 1, so TLC is $6850 \times (5a + 7b) = 34250a + 47950b$. In Fig. 95.2(3), there are 3 *serus*. *seru* 1 has the least flow time and *seru* 3 has the most flow time. Order 1 is finished by *seru* 1, order 2 is *seru* 2 and order 3 is *seru* 3. When arranged order 4, *seru* 2 finishes tasks first, so this order is responsible by *seru* 2. According to this principle, *seru* 1 is responsible for order 1, 5, 8; *seru* 2 is 2, 4, 7; *seru* 3 is 3, 6. The finish time of each order can be seen in the Fig. 95.2(3). Therefore, we can get:

Table 95.4 Several *serus* formations when orders can be splitted

Serus number	*Serus* formation	Appropriate arranged task
1	{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12}	{401}
2	{{1, 2, 3, 4, 5, 6}, {7, 8, 9, 10, 11, 12}}	{203, 198}
3	{{1, 2, 3, 4}, {5, 6, 7, 8}, {9, 10, 11, 12}}	{135, 131, 135}
4	{{1, 2, 3}, {4, 5, 6}, {7, 8, 9}, {10, 11, 12}}	{100, 103, 98, 100}
5	{{1, 2}, {3, 4}, {5, 6}, {7, 8}, {9, 10}, {11, 12}}	{65, 74, 67, 64, 66, 65}
6	{{1, 9}, {2, 12}, {3}, {4}, {5}, {6, 10}, {7, 11}, {8}}	{65, 63, 36, 37, 36, 65, 68, 31}
7	{{1}, {2}, {3, 4, 5}, {6, 10}, {7, 11}, {8}, {9}, {12}}	{33, 32, 108, 65, 68, 30, 33, 32}

$$
\begin{aligned}
TFT_1 &= 6850; TLC_1 = 34250a + 47950b,\\
TFT_2 &= 6864; TLC_2 = 33609a + 47337b,\\
TFT_3 &= 7622; TLC_3 = 33408a + 48652b,\\
TFT_4 &= 7031; TLC_4 = 33066a + 46734b.
\end{aligned}
$$

② Orders can be split

As four *seru* formations are listed, we can deduce that when all workers complete required tasks together the TFT may be less because of little idle time. So we split the orders and arrange them into different *serus* for the best balance, the best balance as the Table 95.4 shown.

According to FCFS principle, appropriate orders arrangement are shown in the Fig. 95.3.

In Fig. 95.3, *seru* formation {{1, 2, 3, 4, 5, 6}, {7, 8, 9, 10, 11, 12}}, and the bottlenecks are worker 2 and worker 8 respectively. $\frac{401}{\left(\frac{1}{\beta_2 \times C_2}+\frac{1}{\beta_8 \times C_8}\right)} \times \frac{1}{\beta_2 \times C_2}$ is 203, which is the number of products arranged to *seru* 1, and the suitable task arranged to *seru* 2 is 198. Orders are allocated to *seru* 1 and 2 one by one and may be split in order to satisfy arrangement. Order 8 is 52 but it is split into 45 and 7 which are allocated to the different *serus*. In Fig. 95.3(2), we calculated the finish time after each order arrangement and the results are signed. In Fig. 95.3(6), there are 8 *serus* and orders are split into several parts for the best balance. Therefore, we can obtain the results as:

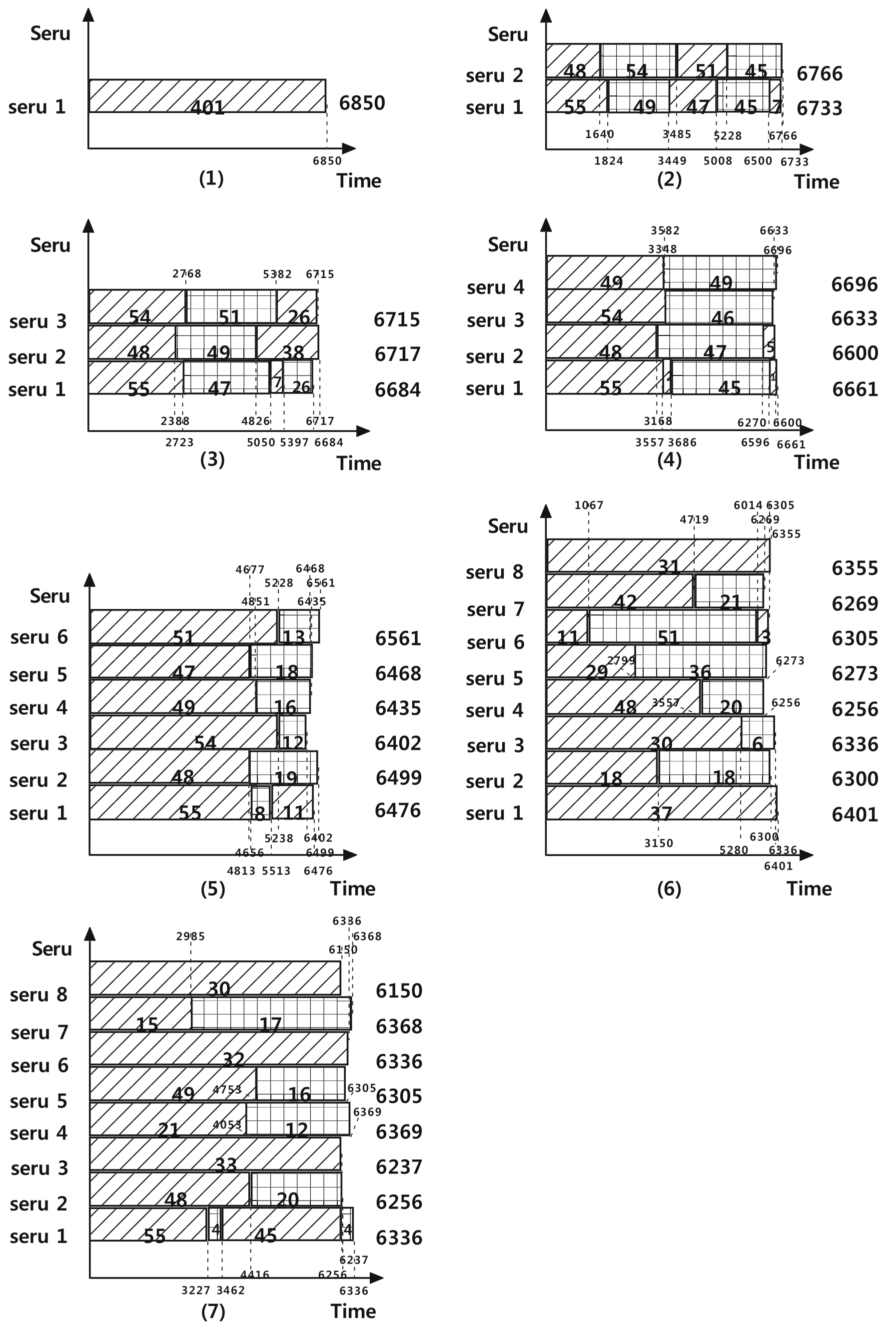


Fig. 95.3 Arrangements of orders (2)

Table 95.5 Optimal solutions in two assembly systems

Assembly systems	TFT	TLC
Conveyor assembly line	10179	122148b
Serus (not split)	6850	$34250a + 47950b$
Serus (split)	6369	$31520a + 44070b$

$$
\begin{aligned}
TFT_1 &= 6850; \quad TLC_1 = 34250a + 47950b,\\
TFT_2 &= 6800; \quad TLC_2 = 33794a + 47188b,\\
TFT_3 &= 6717; \quad TLC_3 = 33548a + 46916b,\\
TFT_4 &= 6696; \quad TLC_4 = 33251a + 46519b,\\
TFT_5 &= 6561; \quad TLC_4 = 32447a + 45235b,\\
TFT_6 &= 6401; \quad TLC_4 = 31549a + 44049b,\\
TFT_7 &= 6369; \quad TLC_4 = 31520a + 44070b.
\end{aligned}
$$

Hence, we can get the optimal solutions as Table 95.5. From the above results, we can see that *seru* has higher efficiency and lower cost than the conveyor assembly line. What's more, whether the orders can be separated or not has a great influence. If the order cannot be split, we will find each *seru* varies a lot in finish time because it may be responsible for the different orders. For example, in Fig. 95.2(3), *seru* 1 and *seru* 2 are responsible for 2 orders, but *seru* 3 for 3 orders. That means *seru* 1 and *seru* 2 have lots of idle time while *seru* 3 is still working. When separate the order, however, each *seru* has nearly same finish time. In this situation, TFT and TLC are reducing increasingly.

95.5.3 Comparison and Analysis

Two production systems in this paper represents the transform from the assembly line to the *seru*. The assembly line becomes shorter and shorter, and the workers' skills and efficiency become higher and higher. Finally, in some systems, the *yatai* may be formed. Here are the detailed comparisons in several aspects:

(1) Efficiency

The ideal type of the assembly system is that every station has the same workload but it is not practical because every process is different and workers' efficiency is affected by various factors. In fact, the assembly system is unbalance with a bottleneck. In the above example of the conveyor assembly line, the productivity is limited by the bottleneck process k. In the other processes, there exists idle time which is a waste of productivity. The total flow time of the conveyor assembly line is 10179. However, in the rotating *serus*, every worker is responsible for production from begin to end. Although workers are affected by the slowest worker, the idle time is much less than the conveyor assembly line. In the *yatai*, the bottleneck worker maybe still the lowest one but the others can work faster and better because everyone is in different *serus*. Without others' effects, workers in their own *serus* can arrange their work plans based on the factory's schedule. As only one worker in *seru*, there is no idle time because all processes are completed by that worker one by one. There are no waiting time and efficiency lost, the productivity rate is nearly 100 %. As the Table 95.5 shown, *seru* has higher efficiency. If the orders are not split, the total flow time is 6850, the efficiency has improved 32.7 %. When orders are split, the efficiency has improved 37.4 % compared with the conveyor assembly line, and 7 percent compared with not split orders. Therefore, better design of *seru* can get better economic benefit.

(2) Workers' Activity

In the conveyor assembly line, every worker completes a simple process based on the theory of division of labor after a short and easy train. Task is monotonous and dull. In the idle time, workers can only wait. Therefore, the activities are low and the turnover rate of workers is high. However, *seru* is a self-learning organization and there are several workers or only one worker in each *seru*, workers have more freedom about how to complete required tasks. They are not only trained into cross-trained but also learn some management knowledge because they may need making some decisions under the authorization system. As a result, workers' enthusiasm are inspired and have better and better performance.

(3) Labor Cost

In the multi-objective model, labor cost is one of the optimal objectives. From the above comparisons, we can conclude that when orders are split the labor cost may be the lowest. The labor cost is related to total flow time and workers' salary level. We suppose that two levels of workers' salary are a and b and $a = 1.2b$. According to Table 95.5, the total labor cost of the conveyor assembly line is $122148b$, and the cost of whether split orders are $89050b$ and $81894b$ respectively. The cost has decreased a lot by 32.7 % compared with the conveyor assembly line. Also, when we split orders, the cost decrease by 7 percent. Training cross-trained workers may be time-consuming but worthwhile because production efficiency will be very high.

95.6 Conclusion

In this paper, we discuss the problem of production system performance improvement based on the bi-objective model with time and cost minimization. Then, we design the solution method for comparison of assembly line-*seru* conversion when considering orders split or not. Finally, we test the model and solution by an numerical example, and the results validates that *seru* production system with order split has a better performance. Although we prove that *seru* has high efficiency and line-*seru* conversion is necessary, many practical factors are not considered in this paper such as the cost of worker training, production of multi-types product, random arrival of orders and so on. All areas are very important and worth our equal concern in the future.

Acknowledgments This research was sponsored by Natural Science Foundation of China (NSFC Grant No. 71401075, 71472089), Jiangsu Provincial Natural Science Foundation of China (Grant No. BK20130753), and the Fundamental Research Funds for the Central Universities (Grant No. JGQN1403).

References

1. Estrada DC, Shukla A, Cochran DS (2000) Converting from moving assembly lines to cells. In: Proceedings of the third world congress on intelligent manufacturing processes and systems, MA, pp 28–30
2. Johnson DJ (2005) Converting assembly lines to assembly cells at sheet metal products: insights on performance improvements. Int Product Res 43(7):1483–1509
3. Kaku I, Murase Y, Yin Y (2008) A study on human-task-related performances in converting conveyor assembly line to cellular manufacturing. Eur J Ind Eng 2(1):17–34
4. Kaku I, Tang J et al (2011) A review: practice and theory in line-cell conversion. INTECH Open Access Publisher, Croatia
5. Liu C, Lian J et al (2010) Seru seisan-an innovation of the production management mode in Japan. Asian J Technol Innov 18(2):89–113
6. Liu C, Yang N et al (2013) Training and assignment of multi-skilled workers for implementing seru production systems. Int J Adv Manufact Technol 69(5–8):937–959
7. Mayumi A (2005) How to deal with reduced volumes. IE Rev 46:45–50 (in Japanese)
8. Ōno T (1988) Toyota production system: beyond large-scale production. Productivity Press
9. Stecke KE, Yin Y et al (2012) Seru: the organizational extension of jit for a super-talent factory. Int J Strateg Decis Sci (IJSDS) 3(1):106–119
10. Takeuchi H (2008) The contradictions that drive toyota's success. Strateg Direction 25(1)
11. Yin Y, Kaku I et al (2006) Converting flow lines to manufacturing cells, another revolution, cellular manufacturing implementations in Japan. In: Proceedings of the third international conference on group technology/cellular manufacturing-GT/CM, pp 94–104
12. Yin Y, Kathryn E et al (2015) Integrating lean and agile production in a highly volatile environment with seru production systems: sony and canon case studies. J Oper Manag
13. Yu Y, Gong J et al (2012) How to carry out assembly line-cell conversion? a discussion based on factor analysis of system performance improvements. Int J Product Res 50(18):5259–5280
14. Yu Y, Tang J et al (2013) Reducing worker (s) by converting assembly line into a pure cell system. Int J Product Econ 145(2):799–806
15. Yu Y, Tang J et al (2014) Mathematical analysis and solutions for multi-objective line-cell conversion problem. Eur J Oper Res 236(2):774–786

Chapter 96
An Improved ACO for the Multi-depot Vehicle Routing Problem with Time Windows

Yanfang Ma, Jie Han, Kai Kang and Fang Yan

Abstract The vehicle routing problem with time windows (VRPTW) is a well-known combinatorial optimization problem often met in many fields of industrial applications. However a logistics company has more than one depot, the VRPTW is not suitable. To overcome this limitation, this paper built the mathematics model of multi-depot vehicle routing problem with time windows (MDVRPTW). The MDVRPTW is a NP-hard problem. To deal with the problem efficiently, an improved Ant Colony Optimization (ACO) is developed in this paper. To improve the performance of ACO, the paper improves the basic ant colony algorithm which can avoids being into local optimal solution and combines the nearest neighbour search method.

Keywords ACO · Multi-depot · Vehicle routing problem · Time windows

96.1 Introduction

With the rapid development of science and technology, the logistics industry has gradually become the artery of national economic development base industry, known as the third profit source of modern enterprises. At present, China's logistics industry is still at the starting stage, and there is a big gap between the developed countries, the most outstanding issue is the higher logistics cost [5]. As the key of logistics optimization system, vehicle routing problems (VRP) research has attracted many people's attention.

Vehicle routing problems (VRP) are well known combinatorial optimization problems, it was firstly proposed by Dantzing and Ramser in 1959 [2]. The VRP is com-

Y. Ma · J. Han · K. Kang (✉)
School of Economics and Management, Hebei University of Technology,
Tianjing 300401, People's Republic of China
e-mail: kkang2000@sina.com

F. Yan
School of Economics and Management, Chongqing Jiaotong University,
Chongqing 400074, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_96

plicated in the real-world application. A number of variations of the traditional VRP have been studied, including the capacitated VRP (CVRP) with service times, the VRP with time windows (VRPTW), the VRP with pick-up and delivery, and the heterogeneous fleet VRP [6]. However, there is a rigid assumption that there is only one depot. In some cases, for example, where a logistics company has more than one depot, the VRP is not suitable. To overcome this limitation, this paper focuses on the VRPTW with multiple depots, or multi-depot VRPTW (MDVRPTW). The objective of the MDVRPTW is to use a series of vehicles from multi-depots, with definite capacity to serve a number of customers with settled demand and hard time windows constraints. As a variant of VRP, MDVRPTW is also a NP-hard problem.

It is difficult to solve this kind of NP-hard problem with accurate algorithms, therefore heuristic algorithms are widely used. Especially with the fast development of biology and physics, more and more useful algorithms which developed from these fields are applied to solve this problem [7]. These algorithms include genetic algorithm, taboo search and particle swarm optimization. However they all have their own drawbacks. The genetic algorithm local search capability is not so strong and the overall quality is not very feasible solution [9]. The tabu search algorithm has a strong dependence on the initial solution. Recently, many scholars have applied ACO algorithm to solve VRP and have gotten some achievements. Some researches on improved ant colony algorithm were proposed in [1, 3, 8], to solve the VRPTW. The Ant Colony Optimization (ACO) method is population-based heuristic method that has been successfully applied to solve several NP-hard combinatorial optimization problems [4]. Its main idea is to integrate each ant's feedback information to find the good solutions collectively. Ant colony algorithm can combine the characteristics of fast speed, global optimization and the answer rationality with finite time. This paper proposes an improved ACO to solve the NP-hard problem MDVRPTW.

The rest of this paper is organized as follows. In Sect. 96.2 we give a detailed description of the MDVRPTW and the mathematical model. In Sect. 96.3 we state in detail the design of the algorithm for solving the problem. Finally, Sect. 96.4 concludes the paper.

96.2 Problem Description and Mathematical Model

96.2.1 Problem Statement

The Multi-depot vehicle routing problem with time windows can be described briefly as follows: A distribution company has multiple depots to serve a set of customers. The number and location of the depots are predetermined. Besides, the location and demand of each customer is given. Each depot is large enough to store all the products ordered by the customers. The objective is to determine a viable delivery sequence of each route which minimizes the delivery costs.

Considering a routing network, it is represented by an undirected graph $G = (V, E)$, where V is a vertex set and E is an arc set. The subset $V_c = \{V_1, V_2, \ldots, V_n\}$ is the customer vertex set. Another subset $V_d = \{V_{n+1}, V_{n+2}, \ldots, V_{n+m}\}$ is the DC

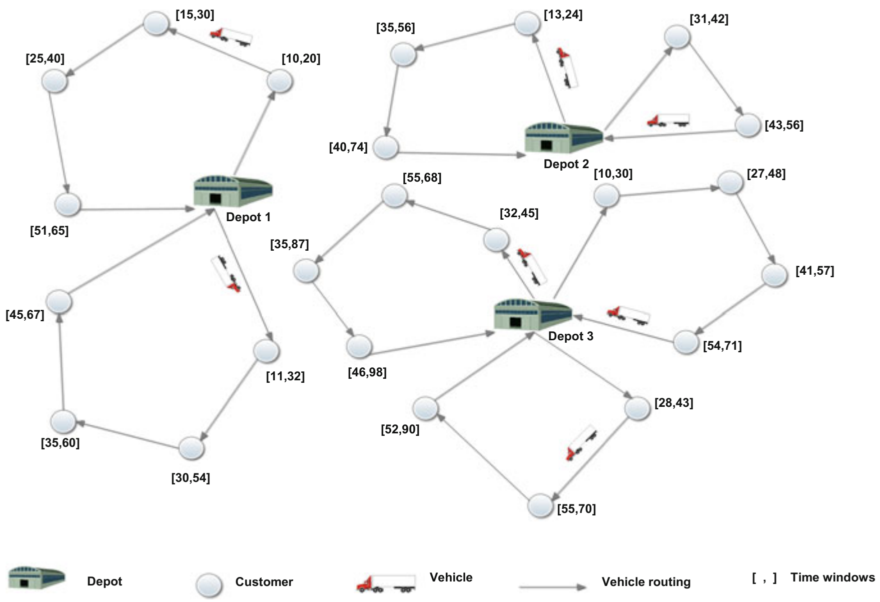


Fig. 96.1 A sketch map of the MDVRPTW

vertex set. The objective of this problem is to find the optimal distribution of vehicles by comparing the costs of different traveling plants. The *MDVRPTW* must satisfy the following conditions:

1. Every customer must be served exactly once by only one vehicle.
2. Every vehicle must start from and return to the same depot.
3. The vehicle can not start from a depot and go to the other one.
4. The total demand of any vehicle route does not exceed the vehicle capacity.
5. Each customer has a service time window $[ET_i, LT_i]$ where ET_i is the earliest time that service can begin and LT_i is the latest time that service can begin.

A sketch map of the MDVRPTW is shown in Fig. 96.1.

96.2.2 Mathematical Model

In order to simplify the problem, we define the sets, parameters and variables used in the mathematical model as follows: We denote the customers by $1, 2, \ldots, N$ and depots by $N+1, N+2, \ldots, N+M$.

Variables:

T_i: service time of customer i
N: total number of customers
M: total number of depots
C_{ij}: cost incurred on arc from node i to j
K_m: total number of vehicles in depot m
ET_i : earliest arrival time at node i
LT_i : latest arrival time at node i
q_i: demand at customer i
Q : fixed capacity of vehicle
s_i : start service time of customer i
t_{ij} : travelling time from customer i to customer j

The mathematical model of *MDVRPTW* is constructed as following:

$$\min \sum_{i=1}^{N+M} \sum_{j=1}^{N+M} \sum_{m=N+1}^{N+M} \sum_{k=1}^{K_m} C_{ij} x_{ij}^{mk}, \tag{96.1}$$

$$\sum_{j=1}^{N} \sum_{k=1}^{K_m} x_{ij}^{mk} \le K_m, \quad i = m \in \{N+1, N+2, \ldots, N+M\}, \tag{96.2}$$

$$\sum_{j=1}^{N} x_{ij}^{mk} = \sum_{j=1}^{N} x_{ji}^{mk} \le 1, \quad \forall k \in \{1, 2, \ldots, K_m\}, i = m \in \{N+1, N+2, \ldots, N+M\}, \tag{96.3}$$

$$\sum_{j=1}^{N+M} \sum_{m=1}^{M} \sum_{k=1}^{K_m} x_{ij}^{mk} = \sum_{j=1}^{N+M} \sum_{m=1}^{M} \sum_{k=1}^{K_m} x_{ji}^{mk} = 1, \quad \forall i \in \{1, 2, \ldots, N\}, \tag{96.4}$$

$$\sum_{i=1}^{N} q_i \sum_{j=1}^{N+M} x_{ij}^{mk} \le Q, \quad k \in \{1, 2, \ldots, K_m\}, m \in \{N+1, N+2, \ldots, N+M\}, \tag{96.5}$$

$$s_{N+1} = s_{N+2} = \cdots = s_{N+M} = 0, \tag{96.6}$$

$$\sum_{m=1}^{M} \sum_{k=1}^{K_m} \sum_{i=1}^{N+M} x_{ij}^{mk} (s_i + T_i + t_{ij}) \le s_j, \tag{96.7}$$

$$ET_i \le s_i \le LT_i, \tag{96.8}$$

$$\sum_{j=N+1}^{N+M} x_{ij}^{mk} = \sum_{j=N+1}^{N+M} x_{ji}^{mk} = 0, \quad i = m \in \{N+1, N+2, \ldots, N+M\}, k \in \{1, 2, \ldots, K_m\}, \tag{96.9}$$

$$x_{ij}^{mk} \in \{0, 1\}. \tag{96.10}$$

The objective (96.1) is to minimize the total vehicle travel cost. Constraint (96.2) limits the number of vehicles going out of the depot m less than K_m. Constraint (96.3) guarantees that each vehicle sets out from the depot and returns to it. Constraint (96.4) ensures that a customer is serviced exactly once by only one vehicle. Constraint (96.5) constrains the vehicle capacity. Constraint (96.6) initializes the beginning time of travelling from the depot. Constraint (96.7) and (96.8) are the time window constraints. Constraint (96.9) ensures that the vehicles could not travel from the depot to depot. Constraint (96.10) is the decision variable constraint, if $x_{ij}^{mk} = 1$, then $s_j = \max(s_i + T_i + t_{ij}, ET_i)$, $i, j \in \{1, 2, \ldots, N + M\}$.

96.3 Improved ACO for MDVRPTW

96.3.1 Transition Rule

Ant colony algorithm is a new type of bionic class of stochastic search algorithm from living world, which was first put forward by the Italian scholar M. Dorigo, V. Maniezzo, A. Colorini. It has teamwork, positive feedback, parallel computing and other characteristics. ACO is summarized by observing the exploitation of food resources among real ants in the natural world. When the ants are creeping between a food source and the nest, they release a trail pheromone on the ground when they return to the nest. The later ants will select the route with a high density of pheromone according to the probability.

When choosing the next node j, it should not only consider the distance between two points, but also consider the time window constraints in the model of MDVRPTW. This paper uses the Nearest Neighbour search method which was proposed by Solomon to solve the VRPTW. The heuristic information contains both time window information and node distance information, combine the two information as a function to make a comprehensive consideration. Let u_{ij} expresses the urgency of node i to node j directly, v_{ij} represents the difference between the completion time of the vehicle in the node i and the arrival time in the node j.

$$\begin{cases} u_{ij} = LT_j - (s_i + T_i + t_{ij}), \\ v_{ij} = s_j - (s_i + T_i), \\ w_{ij} = 1/(w_1 c_{ij} + w_2 u_{ij} + w_3 v_{ij}), \\ w_1 + w_2 + w_3 = 1. \end{cases}$$

The smaller the u_{ij} is, the smaller the difference between the arrival time from node i to node j and the latest arrival time of node j. So the more urgent the require of traveling from node i to node j. In the same way, the smaller the v_{ij}, the smaller the completion time of vehicles in the node i and the arrival time in the node j, then it is more reasonable to travel from node i to node j directly. The smaller the u_{ij}, v_{ij} and c_{ij} are, the bigger the w_{ij} is, so it is more reasonable to travel from node i to node j. In this paper, the heuristic information function is w_{ij}.

When the vehicle k is located at the node i, the following rule is chosen to select the next node j which will be visited. The rule is as follows:

$$\begin{cases} j = \arg \max\limits_{i \in \text{allowed}_k^i} \tau_{ih}^{\alpha} w_{ih}^{\beta}, & r \le r_0, \\ P_{ij}^k = \dfrac{\tau_{ij}^{\alpha} w_{ij}^{\beta}}{\sum_{k \in \text{allowed}_k^i} \tau_{ih}^{\alpha} w_{ih}^{\beta}}, & \text{otherwise.} \end{cases} \tag{96.11}$$

In the above formula, r_0 is a parameter which is given during initialization, $0 < r_0 < 1$. r is a random number between 0 and 1, it is generated when the algorithm is executed. τ_{ij} is the pheromone strength on the edge (i, j), w_{ij} is the heuristic information. P_{ij}^k is the probability for selecting node j. If the random generated number r is less than r_0, then choose the node on which the product of the pheromone value and the heuristic information value is maximum. Otherwise calculate the value of P_{ij}^k. allowed_k^i represents a collection of nodes that are allowed to visit next by the vehicle k at the node i currently. tabu_k is recorded in each step of algorithm implementation.

96.3.2 Pheromone Updating Rule

The pheromone updating includes local updating and global updating. Local updating occurs after finding any feasible path to increase the pheromone intensity of the visited path. Global updating occurs at the end of an iteration to increase the pheromone intensity on the optimal path which is found in the iteration.

When the ant k finds a feasible path, update the pheromone locally on each edge of the path according to the following formula.

$$\begin{aligned} \tau_{ij} &= (1-\rho)\tau_{ij} + \rho \Delta\tau_{ij}^k, \quad i, j = \{1, 2, \ldots, N+M\}, \\ \Delta\tau_{ij}^k &= \begin{cases} \frac{1}{L^k}, & \text{if ant } k \text{ passes the edge } (i, j), \\ 0, & \text{else.} \end{cases} \end{aligned} \tag{96.12}$$

In the updating process, the values of pheromone on each edge are evaporated firstly, the evaporation factor is ρ. If the edge (i, j) is not in the current path which was found by the ant, then $\Delta\tau_{ij}^k = 0$, the retention value is $(1-\rho)$ times of the pheromone after evaporation. If edge (i, j) belongs to the current path, then calculate $\Delta\tau_{ij}^k = \frac{1}{L^K}$, L^k is the length of current path found by the ant k.

After one iteration, make a global pheromone updating on all the paths, focus on increasing the pheromone strength of the optimal path in this iteration. The pheromone is updated according to the following formula. L^* is the length of the shortest path in this iteration.

$$\begin{aligned} \tau_{ij} &= (1-\xi)\tau_{ij} + \xi \Delta\tau_{ij}, \quad i, j = \{1, 2, \ldots, N+M\}, \\ \Delta\tau_{ij} &= \begin{cases} \frac{1}{L^*}, & \text{if edge } (i, j) \text{ belongs to the optimal path}, \\ 0, & \text{else.} \end{cases} \end{aligned} \tag{96.13}$$

In the pheromone updating process, $\tau_{ij}^{(1)} = (1-\rho)\tau_{ij}^{(0)} + \rho\Delta\tau_{ij}^{k} = \tau_{ij}^{(0)} + \rho(\Delta\tau_{ij}^{k} - \tau_{ij}^{(0)})$. The purpose of updating pheromone is to increase the pheromone on the optimal path, so let $\tau_{ij}^{(0)} < \Delta\tau_{ij}^{k} = 1/L^{k}$, similarly, should make $\tau_{ij}^{(0)}$ less than the length of each path which has been found. Make $\tau_{ij}^{(0)} = \frac{1}{N \times 2 \times \max d_{ij}}$, $i \in \{N+1, N+2, \ldots, N+M\}$, $j \in \{1, 2, \ldots, N\}$, $\max d_{ij}$ is the longest distance from each depot to the customer node. The pheromone initialization values are all in the same.

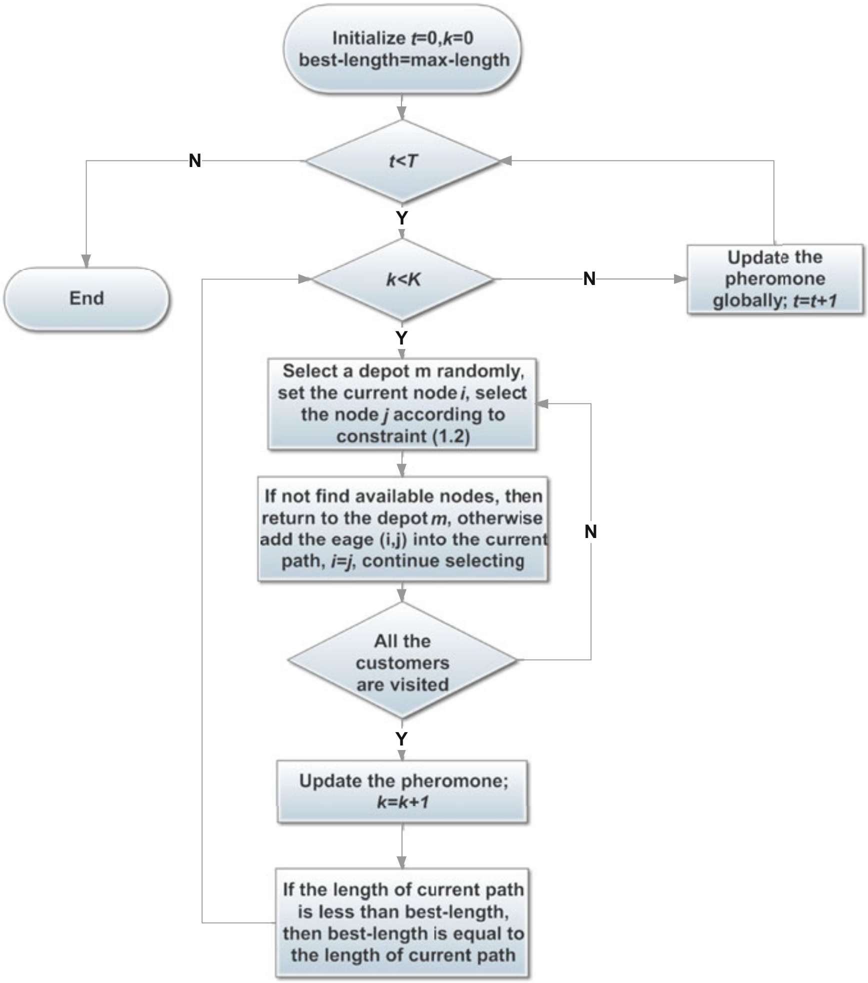


Fig. 96.2 Algorithm flowchart

96.3.3 *Overall Procedure for MDVRPTW*

Step 1. Initialize the variables. Initialize m (the number of ants), α (the pheromone parameter), β (heuristic information strength parameter), ρ and ξ (pheromone evaporation factor). Initialize parameters q_0 and p_0. Set the current ant number $k = 0$.

Step 2. If $k > m$, then go to step 8.

Step 3. For each node i ($i = 1, 2 \ldots, N$), visited $[i] = 0$.

Step 4. Select a depot randomly, use variable start-depot to represent the current depot number and assign variable $i = \text{start} - \text{depot}$.

Step 5. Select the next node i according to formula (96.11).

Step 6. If not find available nodes, then $j = -1$, put the edge (i, start-depot) into the tour. If visited $[i] = 1$ for each node i ($i = 1, 2, \ldots, N$), it indicates that the ant has completed a path search, then update the pheromone of each edge locally according to formula (96.12), $k = k + 1$. If $\text{tour} - \text{length} < \text{best} - \text{length}$, then $\text{best} - \text{tour} = \text{tour}$, $\text{best} - \text{length} = \text{tour} - \text{length}$, return to step 2. If there have unvisited nodes, then $\text{qual} = 0$, return to step 4.

Step 7. Put the edge (i, j) into tour, modify qual into $\text{qual} + q_j$, $s_j = \max(s_i + T_i + t_{ij}, ET_i)$, visited $[j] = 1$, $i = j$, then return to step 3.

Step 8. Update the pheromone of each side globally according to formula (96.13). If the terminating condition is met, output the values of the optimal path and optimal path, then end. Otherwise, turn the ant number $k = 0$, return to step 3.

The algorithm flowchart is shown in Fig. 96.2.

96.4 Conclusions

In the industrial business today, the optimal selection of the vehicle route is a key issue to improve the service quality, reduce the operation cost and increase the profits. In this paper, the MDVRPTW is studied because the number of depots is not limited to one in many real-world situations, an improved ACO algorithm is introduced to solve the MDVRPTW problem. The transition rule and the pheromone updating rule of the whole algorithm are detailed. We improve the optimization search speed effectively and ensure optimal performance of the overall situation. In the future, we plan to combine the ACO with other heuristic algorithms to solve the MDVRPTW.

Acknowledgments This research was supported by NSFC (Grant No. 71401020), NPOPSS (Grant No. 14BGL055), HPOPSS (Grant No. HB15GL111) and Human Social Science for Universities of Hebei (Grant No. SD151011, Grant No. BJ2016057).

References

1. Barán B, Schaerer M (2003) A multiobjective ant colony system for vehicle routing problem with time windows. In: Applied informatics, pp 97–102
2. Dantzig GB, Ramser JH (1959) The truck dispatching problem. Manag Sci 6(1):80–91
3. Lau HC, Sim M, Teo KM (2003) Vehicle routing problem with time windows and a limited number of vehicles. Eur J Oper Res 148(02):559–569
4. Li Z (2010) Improved ant colony optimization for emergency rescue VRP based on matlab. In: 2010 international conference on computer application and system modeling (ICCASM), p 497–499
5. Tao N, Chen G, Tao N (2012) Solving VRP using ant colony optimization algorithm. In: 2012 fifth international conference on information and computing science (ICIC), pp 15–18
6. Toth P, Vigo D (2002) The vehicle routing problem, chapter branch-and-bound algorithms for the capacitated VRP. In: SIAM monographs on discrete mathematics and applications. SIAM
7. Zhang W, Ye J (2010) An improved particle swarm optimization for the multi-depot vehicle routing problem. In: Proceedings of the 2010 international conference on e-business and e-government, pp 3188–3192
8. Zhang W, Lin J et al (2008) Optimizing logistic distribution routing problem based on improved ant colony algorithm. J Zhengjiang Univ Eng Sci 42(4):574
9. Zheng L, Dong D, Wang D (2014) A hybrid intelligent algorithm for the vehicle scheduling problems with time windows. In: 2014 IEEE 17th international conference on intelligent transportation systems (ITSC), pp 2756–2761

Chapter 97
A Novel Inventory and Distribution Planning Model with Non-conforming Items Disposal Under Fuzzy Random Environment

Kai Kang, Wei Pu, Yanfang Ma and Xuguang Wei

Abstract This paper investigates a novel inventory and distribution planning model with non-conforming items disposal (NIDPNCID) under fuzzy random environment to minimize the whole process cost. In this process, a certain fraction or a random number of produced items are defective. These non-conforming items are rejected in order to improve the consumer satisfaction. To solve the problem, a dynamic programming-based particle swarm optimization (DP-based PSO) algorithm with fuzzy random simulation is proposed, which can be easy to implement. In more specific terms, DP-based PSO can reduce the dimensions of a particle by using the state equation, which significantly reduced the solution space.

Keywords Inventory · Non-conforming items · Distribution · Fuzzy random · Particle swarm optimization algorithm

97.1 Introduction

In complex supply chains where products and components of products are manufactured in many different facilities, inventory and distribution costs make up a significant proportion of total network costs. Most manufacturing enterprises are organized into networks of manufacturing and distribution sites that procure raw material, process them into finished goods, and distribute the finish goods to customers. Inventory and distribution are even more important in large-scale projects because unsuitable inventory level and delivery route can lead to big losses for the project.

K. Kang · W. Pu · Y. Ma (✉) · X. Wei
School of Economics and Management, Hebei University of Technology, Tianjin, People's Republic of China
e-mail: mayanfang@hebut.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_97

In real world situations, a single-item inventory seldom occurs and multi-item inventory is common. There is a vast amount of literature on inventory placement models for multi-stage systems that is applicable to inventory and distribution problem [2, 4, 6]. Normally, a production process is not completely perfect. It may result in producing some defective items from the very beginning of the commencement of production. Here defective items may be an uncertain fraction of the total purchase quantity [9]. As the production continues, the production process deteriorates, and as a result, a random number of defective products are produced. These non-conforming items can be dealt by the supplier in the way of rejection. Under this scenario, penalty cost of shortage is evaluated. In this paper, in order to have maximum profit for the cases when the number of defective items per unit time is deterministic or random. Generally speaking, the novel inventory and distribution planning model with non-conforming items disposal (NIDPNCID) covers a wide range of formulations ranging from simple single supplier type to complex multi-supplier type, and from single-stage deterministic models to complex multi-stage models.

In recent years, population based stochastic local search techniques have been successfully used as effective solution tools, though relatively new, in the field of optimization. There are several nature inspired techniques belonging to this family that use metaphors as guides in solving problems, such as tabu search [1], local search [3], simulated annealing [7], genetic algorithms [8], and ant colony optimization [10]. Among these algorithms, particle swarm optimization (PSO) is an evolutionary computation technique developed by Kennedy and Eberhart in 1995 [5]. PSO is a population-based optimization tool. The system is initialized with a population of random solutions, searching for optima by updating generations. In PSO, the potential solutions, called "particles", are "flown" through the problem space by following the current optimum particles. Considering the relationship among state equation, constraint conditions, and objective function of the problem, DP-based PSO algorithm has been organized, which can reduce the dimensions of a particle by using the state equation in the dynamic programming model. Here, DP-based PSO algorithm is developed to solve the model of our research problem.

The paper is organized as follows: the research problem and statement of the novel inventory and distribution planning model with non-conforming items disposal (NIDPNCID) under an uncertain environment is introduced is Sect. 97.2. Section 97.3 explains the modeling of the fuzzy random dynamic programming model. Section 97.4 describes a DP-based particle swarm optimization algorithm to solve the model. Finally, some concluding remarks are outlined in Sect. 97.5.

97.2 Key Problem Statement

The aim of this paper is to present a novel inventory and distribution planning model with non-conforming items disposal (NIDPNCID), mainly as far as the incoming non-conforming materials problem is concerned. To minimize the cost approach to this problem, while taking into consideration the purchase cost, transport cost and

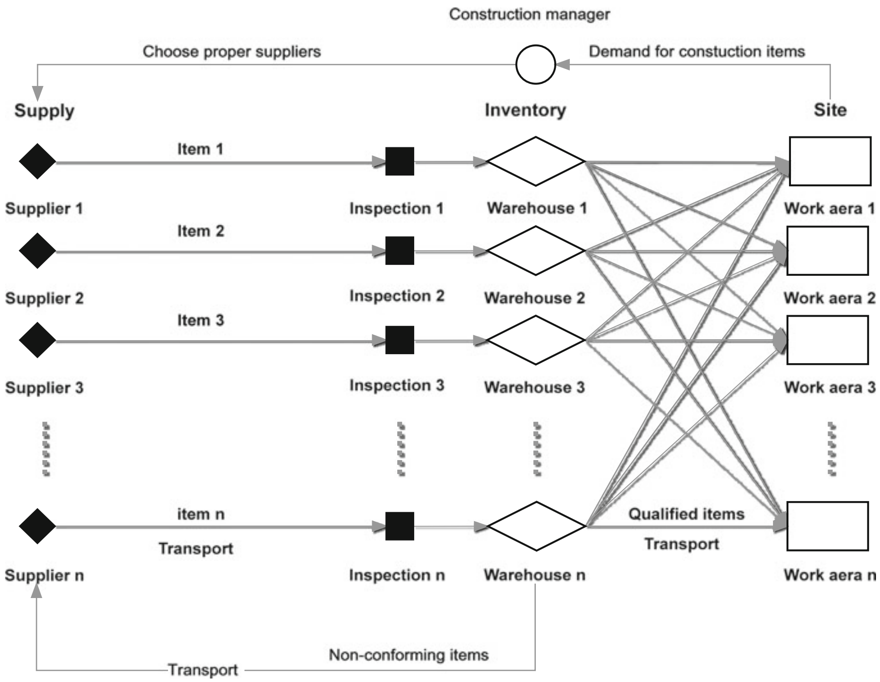


Fig. 97.1 The flow of materials

focuses on inventory cost and on penalty cost. The flow of materials can be shown in Fig. 97.1. In the literature, the problem of optimizing inventory and distribution management is generally considered in two stages. The first is quality inspection before transporting into warehouses to make sure that each item transported into warehouse is qualified. The second stage is the problem of returned non-conforming products to the contractor. The assumptions are as follows: (1) The materials demand, transportation price, item fraction defective and inventory cost conversion factor in every stage are regarded as fuzzy random variables. (2) The span of every stage is identical to each other. (3) The penalty cost is used to reduce the losses because of shortage. (4) Costs incurred during the way back to supplier should be the suppliers to burden. (5) Every kind of item has a corresponding warehouse to be stored and with a maximum storage capacity for each item, then the materials will be first transported from the suppliers to the warehouses, then from the warehouses to the construction sites. (6) The lead time is zero, hence at the beginning of every stage, all purchased items will arrive at their corresponding warehouse.

97.3 Modelling

97.3.1 Notations

In order to facilitate the problem description, the following notations are introduced.

Indices

i: Stage index; $i \in \Phi = \{0, 1, \ldots, k-1\}$;
t: Item index; $t \in \Psi = \{1, 2, \ldots, n\}$.

Fuzzy Random Variables

$\overline{\tilde{\tilde{Y}}_t}$: The transportation price of Item t from the supplier to the corresponding warehouse;
$\overline{\tilde{\tilde{Z}}_t}$: The transportation price of Item t from the warehouse to the construction sites;
$\overline{\tilde{\tilde{u}}_t}(i)$: The demand for Item t in the $(i+1)$th stage;
$\overline{\tilde{\tilde{X}}_t}$: The conversion factor of Item t in the $(i+1)$th stage;
$\overline{\tilde{\tilde{q}}_{t,i}}$: The fraction defective of Item t in the $(i+1)$th stage.

Variables and Parameters

S_t: The initial inventory level of Item t at the beginning of the first stage;
T_t: The terminal inventory level of Item t at the end of the whole duration;
η_t: The rise and fall rate for the price of Item t;
ξ_t: The spot price of Item t in the first stage;
c_t: The discount percentage of maximum purchase quantity of Item t;
$P_{t,i}^{\max}$: The maximum purchase quantity of Item t in the $(i+1)$th stage;
$P_{t,i}^{\min}$: The minimum purchase quantity of Item t in the $(i+1)$th stage;
$Q_t^{\max}$: The maximum inventory level of Item t;
$l_t(i)$: The inventory level of Item t in the corresponding warehouse at the beginning of the $(i+1)$th stage;
$x_t(i)$: The purchase quantity of Item t in the $(i+1)$th stage;
$\delta_t(i)$: The option premium of Item t in the $(i+1)$th stage;
$\gamma_t(i)$: The conversion coefficient of Item t in the $(i+1)$th stage.
K_t: The unit storage cost of Item t;
$L_t(s)$: The function of current inventory for Item t in the whole construction duration;
d_t: The inspection fee of Item t;
r_t: The return price of defective Item t;
σ_t: The stock out penalty price of defective Item t.

97.3.2 Global Model

The global model can be described as follows, and objective functions, state equation and constraint conditions are represented below.

$$\min F^{PC}(x_t, \xi_t, \eta_t) = \sum_{i=0}^{k-1}[\delta_t(i) + \gamma_t(i)\xi_t(1+\eta_t)^i x_t^2(i)] \quad \forall t \in \Psi, \quad i \in \Phi, \tag{97.1}$$

$$\min F^{TC}(x_t, \widetilde{\widetilde{u_t}}, \widetilde{\widetilde{Y_t}}, \widetilde{\widetilde{Z_t}}) = \sum_{i=0}^{k-1}[\widetilde{\widetilde{Y_t}} x_t(i) + \widetilde{\widetilde{Z_t}}\widetilde{\widetilde{u_t}}(i)], \tag{97.2}$$

$$\min F^{IC}(x_t, l_t, \widetilde{\widetilde{q_{t,i}}}, d_t, r_t) = \sum_{i=0}^{k-1}\widetilde{\widetilde{X_t}} K_t l_t(i) + \sum_{i=0}^{k-1} x_t(i) d_t - \sum_{i=0}^{k-1} x_t(i)\widetilde{\widetilde{q_{t,i}}} r_t, \tag{97.3}$$

$$\min F^{PeC}(x_t, l_t, \widetilde{\widetilde{u_t}}) = \sum_{i=0}^{k-1}\sigma_t[\widetilde{\widetilde{u_t}}(i) - l_t(i) - (1-\widetilde{\widetilde{q_{t,i}}})x_t(i)] \quad \forall t \in \Psi, \quad i \in \Phi, \tag{97.4}$$

$$s.t. \quad \delta_t(i) + \gamma_t(i)\xi_t(1+\eta_t)^i (P_{t,i}^{\min})^2 = \xi_t(1+\eta_t)^i P_{t,i}^{\min}, \tag{97.5}$$

$$\delta_t(i) + \gamma_t(i)\xi_t(1+\eta_t)^i (P_{t,i}^{\max})^2 = \xi_t c_t(1+\eta_t)^i P_{t,i}^{\max}, \tag{97.6}$$

$$\widetilde{\widetilde{X_t}} K_t l_t(i)[(i+1) - i] = \int_i^{i+1} K_t L_t(s) ds \quad \forall t \in \Psi, \quad i \in \Phi, \tag{97.7}$$

$$l_t(i+1) = [l_t(i) + x_t(i)(1-\widetilde{\widetilde{q_{t,i}}}) - \widetilde{\widetilde{u_t}}(i)]^+, \quad \forall t \in \Psi, \quad i \in \Phi, \tag{97.8}$$

$$l_t(0) = S_t, \quad \forall t \in \Psi, \tag{97.9}$$

$$l_t(k) = T_t, \quad \forall t \in \Psi, \tag{97.10}$$

$$P_{t,i}^{\min} \le x_t(i) \le P_{t,i}^{\max}, \quad or \quad x_t(i) = 0, \qquad \forall t \in \Psi, \quad i \in \Phi, \tag{97.11}$$

$$0 \le l_t(i) \le Q_t^{\max} \quad \forall t \in \Psi, \quad i \in \Phi, \tag{97.12}$$

$$\Psi = \{1, 2, \ldots, n\}, \tag{97.13}$$

$$\Phi = \{0, 1, \ldots, k-1\}. \tag{97.14}$$

The objective functions define the total cost during the whole project. The aim of the project controller is to minimize the total cost for all the items they purchase during the whole process, simultaneously. The total cost formed by four constituent parts: purchase cost, transport cost, inventory cost, and penalty cost. (1) In practice, most large scale projects have introduced a new way to determine the purchase price. In this paper, the most practical pricing formula is considered to be used in the NIDPNCID. Equation (97.1) describes the purchase cost, and $\delta_t(i)$ and $\gamma_t(i)$ can be calculated from Eqs. (97.5) and (97.6). (2) The transportation distance among suppliers, warehouse and construction sites is different, the transportation vehicle are different. The transportation price naturally is complicated. Hence, let F^{TC} be the total transportation cost of Item t, it can be presented as Eq. (97.2). (3) Let K_t be the unit inventory cost of Item t, it is not hard to find that the actual cost of inventory should be less than $K_t l_t(i)$. Then an inventory conversion factor should be introduced to balance the difference between actual inventory quantity and $l_t(i)$. $L_t(s)$ is sited as the function of current inventory for Item t, in which the unit of Item t is one stage and $L_t(i) = l_t(i)$, then the inventory conversion factor $\overline{\widetilde{X_t}}$ can be defined as Eq. (97.7) Let d_t be the inspection fee of Item t. Before transported into warehouse, every unit of item should be inspected. Then the non-confirming item need to be returned to suppliers, and request for return price. Since purchase quantity is present as $x_t(i)$, all inspection fee should naturally be $x_t(i)d_t$. Let $\overline{\widetilde{q_{t,i}}}$ be the fraction defective of Item t. Let F^{IC} be the total inventory price, it can present as Eq. (97.3). (4) The penalty cost describes the penalty if the qualified product of Item t can not be met. Let σ_t be the penalty if the demand of qualified product of Item t can not be met in $(i+1)$th stage. Let F^{PeC} be the penalty cost of Item t, it can get from Eq. (97.4).

The state equation describes the relationship between stage ith and stage $(i+1)$th. Let $l_t(i)$ be the inventory level, $x_t(i)$ be purchase quantity, and $\overline{\widetilde{u_t}}(i)$ be demand. Let $\overline{\widetilde{q_{t,i}}}$ be the fraction defective of Item t, if the item purchased is inspected to be qualified, then it transport to the warehouse, the inventory level of Item t in the corresponding warehouse at the beginning of the $(i+2)$th stage, $l_t(i+2)$, should be $l_t(i) + x_t(i)(1 - \overline{\widetilde{q_{t,i}}}) - \overline{\widetilde{u_t}}(i)$, or $l_t(i+2)$ should be zero. The relationship among the inventory level, purchase quantity, and demand can be present as Eq. (97.8).

The initial conditions describe the storage level of the Item t before the begin stage. The terminal conditions describe the storage level of the Item t at the end of the whole duration. Let St be the terminal inventory level of Item t. The initial condition and terminal condition can be present mathematically as Eqs. (97.9) and (97.10), separately. Generally, in the practical condition, the two conditions above can be settled as: $St = 0$ and $Tt = 0$, $\forall t \in \Psi$. If controller decide to buy Item t on stage $(i+1)$th, Let $P_{t,i}^{\min}$ and $P_{t,i}^{\max}$ be the minimum purchase quantity of Item t and maximum purchase quantity of Item t in the stage $(i+1)$th, separately. The purchase quantity of it in every stage should be within the specified range between them, which can be present as Eq. (97.11). As the maximum storage level must be taken into consideration, inventory level of every item in every stage can not exceed the maximum storage level. Define $Q_t^{\max}$ as the maximum storage of Item i, the storage level $l_t(i)$ should satisfy the conditions Eq. (97.12).

97.4 Dynamic Programming-Based PSO

With appropriate model transformations, a dynamic programming-based particle swarm optimization (DP-based PSO) algorithm is developed to solve the model. The notations needed are as follows:

τ: iteration index, and $\tau = 1, 2, \ldots T$.
d: dimension index, and $d = 1, 2, \ldots, D$.
l: particle index, $l = 1, 2, \ldots, N$.
w: inertia weight.
$v_{ld}(\tau)$: velocity of the lth particle at the dth dimension in the τth iteration.
$p_{ld}(\tau)$: position of the lth particle at the dth dimension in the τth iteration.
p_{ld}^{best}: personal best position of the lth particle at the dth dimension.
p_{gd}^{best}: global best position at the dth dimension.
c_1: personal best position acceleration constant.
c_2: global best position acceleration constant.
$P_l(\tau)$: vector position of the ith particle, and $P_l = [p_{l1}, p_{l2}, \ldots, p_{lD}]$.
V_l: vector velocity of the ith particle, and $V_l = [v_{l1}, v_{l2}, \ldots, v_{lD}]$.
P_l^{best}: vector personal best position of the lth particle, $P_l^{\text{best}} = [p_{l1}^{\text{best}}, p_{l2}^{\text{best}}, \ldots, p_{lD}^{\text{best}}]$.
P_g^{best}: vector global best position, and $P_g^{\text{best}} = [p_{g1}^{\text{best}}, p_{g2}^{\text{best}}, \ldots, p_{gD}^{\text{best}}]$.
$Y_l^i(\tau)$: the ith part of the lth particle in the τth generation.

97.4.1 General Mechanism of DP-Based PSO

Particle swarm optimization (PSO) is an optimization technique based on swarm intelligence, proposed by Kennedy and Eberhart [5]. It simulates a social behavior such as birds flocking to a promising position for certain objectives in a multidimensional space. While there have been many variants of the algorithm since its introduction, in this study, based on the iterative dynamic programming model, a DP-based PSO algorithm is developed to solve the problem. Unlike the standard PSO, DP-based PSO can reduce the dimensions of a particle by using the state equation in the dynamic programming model. For this problem, the problem dimension should contain decision variables and state variables, both appear in the objectives and constraints. It should be noted that if the decision variables are known, then the state variables can be calculated by using the state equation.

Throughout the optimization process of DP-based PSO, each lth particle in the τth generation monitors its current position $P_l(\tau) = [p_{l1}(\tau), p_{l2}(\tau), \ldots, p_{lD}(\tau)]$, the best position it has ever reached $P_l^{\text{best}} = [p_{l1}^{\text{best}}, p_{l2}^{\text{best}}, \ldots, p_{lD}^{\text{best}}]$, and its flying velocity $V_l = [v_{l1}, v_{l2}, \ldots, v_{lD}]$. The search benefits from sharing information of particles discoveries and past experience with the whole population. In each generation, the global best position $P_g^{\text{best}} = [p_{g1}^{\text{best}}, p_{g2}^{\text{best}}, \ldots, p_{gD}^{\text{best}}]$ is calculated as the best position that the swarm has ever reached.

Then, each particle updates its velocity V_l to approach the global best position and its personal best position:

$$V_l(\tau + 1) = \omega V_l(\tau) + c_p r_p(P_l^{\text{best}} - P_l(\tau)) + c_g r_g(P_g^{\text{best}} - P_l(\tau)), \qquad (97.15)$$

where $l = 1, 2, \ldots, N$; L is the population size; $\tau = 0, 1, \ldots, T$; T is the iteration limit; $P_l^{\text{best}} = [p_{l1}^{\text{best}}, p_{l2}^{\text{best}}, \ldots, p_{lD}^{\text{best}}]$, the personal best of the lth particle encountered after τ iterations; $P_g^{\text{best}} = [p_{g1}^{\text{best}}, p_{g2}^{\text{best}}, \ldots, p_{gD}^{\text{best}}]$, the global best among all the swarm of particles achieved so far. c_p and c_g are learning factors that determine the relative weight that the global best has versus the personal best. r_p and r_g are random numbers between 0 and 1; and $\omega(\tau)$ is the inertia weight used to control the impact of the previous velocities on the current velocity, which influences the trade-off between the global and the local exploration abilities during the search. The particle then updates positions using the new velocity:

$$P_l(\tau + 1) = V_l(\tau + 1) + P_l(\tau). \tag{97.16}$$

The essential differences between the DP-based PSO and the standard PSO is that the DP-basd PSO takes advantage of the iterative mechanism of dynamic programming model to reduce the dimensions of the particles, so that the solution search space is significantly reduced. It should be noted that, in this study, if we use the standard PSO, the dimensions of a particle will be $2n \times m$ as compared to $n \times m$, the size of a DP-basd PSO particle.

$$P_l(\tau) = [p_{l1}(\tau), p_{l2}(\tau), \ldots, p_{lD}(\tau)] = [Y_1^1(\tau), Y_l^2(\tau), \ldots, Y_l^N(\tau)]. \tag{97.17}$$

where $Y_l^j(\tau)$ can be the jth part of the lth particle in the τth generation. Note that every part of a particle is a m-dimension vector, and can be denoted as:

$$Y_l^j(\tau) = [y_{l1}^j(\tau), y_{l2}^j(\tau), \ldots, y_{lm}^j(\tau)], \tag{97.18}$$

where $y_l^j(i+1)(\tau)$ be the $(i+1)$th dimension of $Y_l^j(\tau)$ for the lth particle in the τth generation; $i = 0, 1, \ldots, m-1$. In order to be in line with the expression $P_l(\tau) = [p_{l1}(\tau), p_{l2}(\tau), \ldots, p_{lD}(\tau)]$, $y_l^j(i+1)(\tau) = p_{l(m\times(j-1)+i+1)}(\tau)$.

97.4.2 Overall Procedure of DP-Based PSO

Based on the above sections, the overall procedure of the DP-based PSO algorithm can be given. The details of this algorithm are as follows:

Step 1. Initialize the swarm base on DP-based PSO.

- **Step 1.1** Set $t = 1, i = 0$.
- **Step 1.2** Initialize $y_l^j(i+1)(\tau)$ by generating a random real number within $[P_{t,i}^{\min}, P_{t,i}^{\max}]$. Then, based on $l_t(i+1) = [l_t(i) + x_t(i)(1 - \widetilde{q_{t,i}}) - \widetilde{u_t}(i)]^+$ (note that $l_i(0) = S_t$, where S_t denotes the initial inventory level of Item t in the warehouse at the beginning of the first stage).

Step 1.3 If $0 \leq l_t(i) \leq Q_t^{\max}$, then go to Step 1.4. Otherwise, return to Step 1.2.

Step 1.4 If the stopping criterion is met, i.e., $t = n$ and $i = k - 1$, then the initialization for the lth particle is completed. Otherwise, $i = i + 1$ and return to Step 1.2.

Step 2. Calculate initial particles to generate the fitness value. P_l^{best} and the P_g^{best}.

Step 3. Update the particle positions and velocities.

Step 3.1 Generate the P_l and adapt it to the feasible region.

Step 3.1.1 Set $t = 1, i = 0$.

Step 3.1.2 If $y_l^j(i+1)(\tau) < P_{t,i}^{\min}$, then $y_l^j(i+1)(\tau) = P_{t,i}^{\min}$. If $y_l^j(i+1) > P_{t,i}^{\max}$, then $y_l^j(i+1) = P_{t,i}^{\max}$.

Step 3.1.3 Based on $l_t(i+1) = [l_t(i) + x_t(i)(1 - \widetilde{\widetilde{q_{t,i}}}) - \widetilde{\widetilde{u_t}}(i)]^+$.

Step 3.1.4 If $0 \leq l_t(i) \leq Q_t^{\max}$, then go to Step 5. Otherwise, let $U = l_t(i+1) - Q_t^{\max}$, $y_l^j(i+1) = y_l^j(i+1) - U$, return to Step 3.1.3.

Step 3.1.5 If $i = k - 1$, then $i = i + 1$ and go to Step 3.1.6. Otherwise, $i = i + 1$ and return to Step 3.1.2.

Step 3.1.6 If the stopping criterion is met, i.e., $t = n$ and $i = k - 1$, then the adjustment for the lth particle is completed. Otherwise, $k = k + 1$ and return to Step 3.1.2.

Step 3.2 Update the personal best, if $\text{Fitness}(P_l) > \text{Fitness}(P_l^{\text{best}})$, $P_l^{\text{best}} = P_l$.

Step 3.3 Update the global best, if $\text{Fitness}(P_l) > \text{Fitness}(P_g^{\text{best}})$, $P_g^{\text{best}} = P_l$.

Step 3.4 Update the velocity and the position of each particle according to Eqs. (97.16) and (97.17).

Step 4. If the stopping criterion is met, then go to Step 5; otherwise, $\tau = \tau + 1$ and return to Step 3.

Step 5. Get the fitness value and the global best position, then decoding the particle to get the problem solution.

Step 5.1 Decode the $(i+1)$th dimension of $Y_l^j(\tau)$ (i.e., $y_l^j(i+1)(\tau)$) into the purchase quantity of Item t at the beginning of the $(i+1)$th stage, i.e., $x_t(i) = y_l^j(i+1)(\tau), t = 1, 2, \ldots, n, i = 0, 1, \ldots, k-1$.

Step 5.2 Set $t = 1, i = 0$.

Step 5.3 Based on $l_t(i+1) = [l_t(i) + x_t(i)(1 - \widetilde{\widetilde{q_{t,i}}}) - \widetilde{\widetilde{u_t}}(i)]^+$.

Step 5.4 If the stopping criterion is met, i.e., $t = n$ and $i = k - 1$, then integrate $x_t(i)$ and $l_t(i)$ (for $t = 1, 2, \ldots, n, i = 1, 2, \ldots, k - 1$) in order to form a solution to the NIDPNCID. Otherwise, if $i = k - 1$, then $t = t + 1$ and return to Step 3. If $i < m - 1$, then $i = i + 1$ return to Step 5.3.

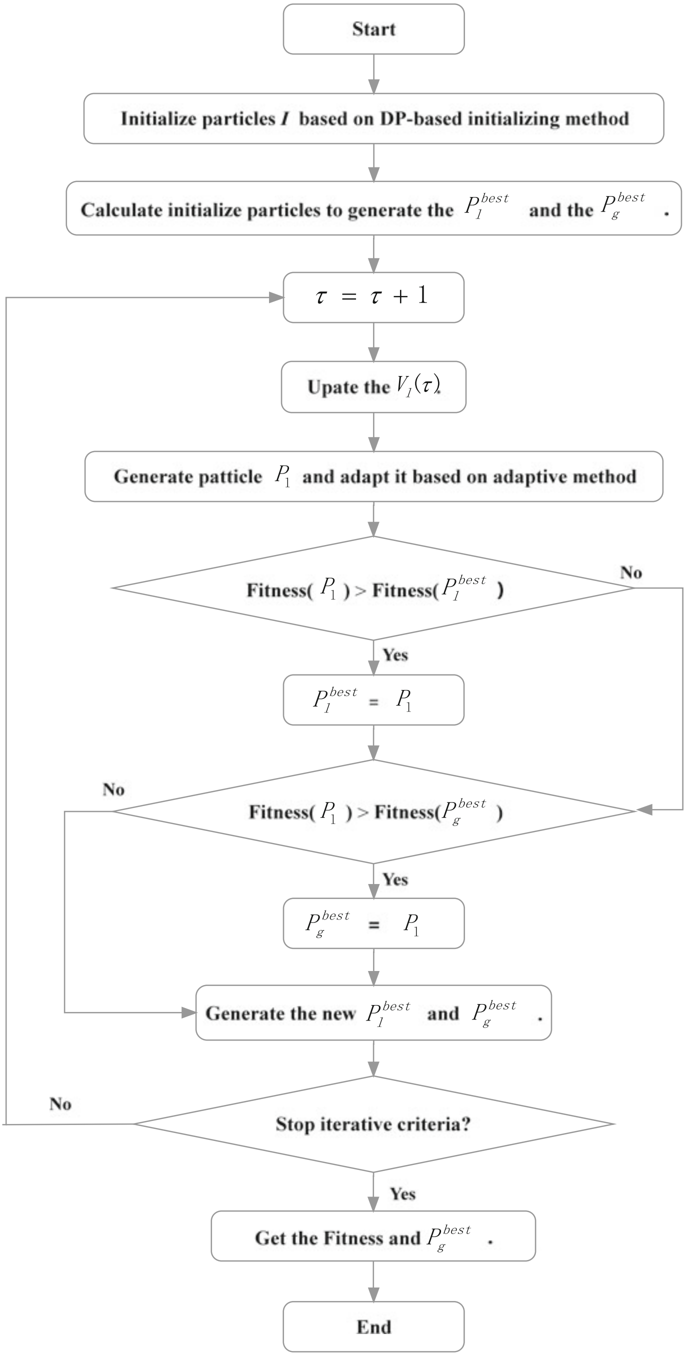


Fig. 97.2 General framework

It can be seen the algorithm clearly from Fig. 97.2, which is the overall procedure for the DP-based PSO algorithm.

97.5 Conclusion

In this paper, we present a novel inventory and distribution planning model with non-conforming items disposal (NIDPNCID) under fuzzy random environment. In our model, every cost is considered to be fuzzy random variables, and the project controller is the leader trying to minimize the total costs which contains purchase cost, transport cost inventory cost and on penalty cost. Furthermore, a heuristic solution algorithm is proposed to solve this problem, namely dynamic programming-based particle swarm optimization (DP-based PSO) algorithm with fuzzy random simulation. The findings of my research extend to those of prior studies, which mostly have assumed the items are qualified and neglect the effects of non-confirming items on the process of purchase. Improvements of this work are currently under consideration, including the cooperative outsourcing.

Acknowledgments This research was supported by NSFC (Grant No. 71401020), NPOPSS (Grant No. 14BGL055), HPOPSS (Grant No. HB15GL111) and Human Social Science for Universities of Hebei (Grant No. SD151011, Grant No. BJ2016057).

References

1. Badeau P, Guertin F et al (1997) A parallel tabu search heuristic for the vehicle routing problem with time windows. Transp Res Part C Emerg Technol 5(2):109–122
2. Bhattacharya D (2005) On multi-item inventory. Eur J Oper Res 162(3):786–791
3. Duhamel C, Lacomme P et al (2011) A multi-start evolutionary local search for the two-dimensional loading capacitated vehicle routing problem. Comput Oper Res 38(3):617–640
4. Feng J, Liu L, Yw Wan (2010) Order-based backorders in multi-item inventory systems. Oper Res Lett 38(1):27–32
5. Kennedy J, Eberhart R (1995) Particle swarm optimization. In: Proceedings of IEEE international conference on neural networks, vol 4, 1942–1948. IEEE, New York
6. Kiesmüller GP (2010) Multi-item inventory control with full truckloads: a comparison of aggregate and individual order triggering. Eur J Oper Res 200(1):54–62
7. Kuo Y (2010) Using simulated annealing to minimize fuel consumption for the time-dependent vehicle routing problem. Comput Ind Eng 59(1):157–165
8. Lau H, Chan T et al (2010) Application of genetic algorithms to solve the multidepot vehicle routing problem. IEEE Trans Autom Sci Eng 7(2):383–392
9. Rezaei J, Davoodi M (2008) A deterministic, multi-item inventory model with supplier selection and imperfect quality. Appl Math Model 32(10):2106–2116
10. Yu B, Yang ZZ, Yao B (2009) An improved ant colony optimization for vehicle routing problem. Eur J Oper Res 196(1):171–176

Chapter 98
A Multi-objective Distribution-Return Center Layout Problem in Closed-Loop Supply Chain Under Fuzzy Random Environment

Yanfang Ma, Xiaoyu Wang, Kai Kang and Fang Yan

Abstract This paper presents a model for a multi-objective distribution-return center of closed loop supply chain layout problem, where the objective is to minimize the transportation cost, operation cost and transportation pollution. Uncertainties in the form of randomness and fuzziness are handled together in this paper for a better solution of the problem. The returned products and the unavailable products are considered as fuzzy random variables. A heuristic algorithm based on PSO is applied to give reliable solutions for this NP-hard problem.

Keywords Distribution-return center · Closed-loop supply chain · Fuzzy random variable · Particle swarm optimization

98.1 Introduction

Due to the resource scarcity and environmental concerns, the forward and reverse material flows need to coordinate in supply chain. The growing need for remanufacturing and recycling leads to the design of closed loop supply chain (CLSC). CLSC consists of the traditional supply chain (forward supply chain) and the reverse supply chain, in which activities such as collection, remanufacturing, and refurbishing are concluded [3]. Here, decisions are made that some products need repair, some are send to the manufacturers to be remanufactured, the unavailable ones are forwarded to the disposal centers [8].

There are a lot of decision making problems in the closed-loop supply chain, one of which is the location of distribution centers, collection centers, and disposal centers

Y. Ma · X. Wang · K. Kang (✉)
School of Economics and Management, Hebei University of Technology,
Tianjing 300401, People's Republic of China
e-mail: kkang2000@sina.com

F. Yan
School of Economics and Management, Chongqing Jiaotong University,
Chongqing 400074, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_98

[8]. Earlier publications can provided evidence about the necessity of combination of the distribution center and the return center. Considering the layout problem of the distribution-return centers is of great importance. Yang [10] had researched into the allocation of the distribution center, return center and distribution-return center. This paper focus on the layout of the distribution-return center.

The uncertainties involved in the reverse flow due to their natures are higher than those involved in the forward supply chain. Subjective uncertainties such as decision makers's choice, can be dealt by fuzziness. Objective uncertainties such as unit transportation cost, product prices, the quantity of products which can not be reused anymore, can be dealt with randomness. Both randomness and fuzziness exist in the real world. Maryam [5] and Fallah [2] thought uncertainties existed in customers' demands and the amount of returned products. Utilized target/ threshold is considered as uncertainties in Kemal's paper [7]. They are simultaneously considered in this paper.

The distribution-return center layout problem in closed-loop supply chain (DRCLPCLSC), which is under fuzzy random environment, is an NP-hard problem. Dealing with the DRCLPCLSC requires effective solution approaches, which can give us reliable solutions in a reasonable time especially for real-size problems. Conventional exact methods are only able to tackle relatively small problems and are therefore not suitable for distribution-return centers layout problems with milt-objective due to the difficulty in finding a optimal solution. Heuristic algorithms have attracted researchers attention. Genetic algorithm is used to solve the closed-loop supply chain design problem [1]. Particle swarm optimization (PSO) has shown its potential in solving NP-hard problems [9]. Compared with genetic algorithm, PSO has strengths in preserving the best solution of all iteration and the best result of every single solution [6]. In this paper, A heuristic algorithm based on PSO is applied to solve the DRCLPCLSC.

This paper is organized as follows: Sect. 98.2 presents the problem statement and model assumptions. A description of the model and its formulation are given in Sect. 98.3. The proposed hybrid solution based on PSO is described in Sect. 98.4. Finally, Sect. 98.5 provides a conclusion of this paper.

98.2 Research Problem Statement

There are four stages along a closed-loop supply chain: factories, distribution-return centers, markets and waste disposal centers. The initial problem of this article is making decisions regarding the proper places of the distribution-return centers among candidates while pursuing minimal operation costs, minimal transportation costs and minimal transportation pollution, considering the flow constraints, and satisfying the market demands. The distribution-return center can provide the decision makers with less construction cost and transportation cost, because the distribution-return center can use the same vehicles when distribute and recycle. So we consider distribution-return center rather than distribution center or return center.

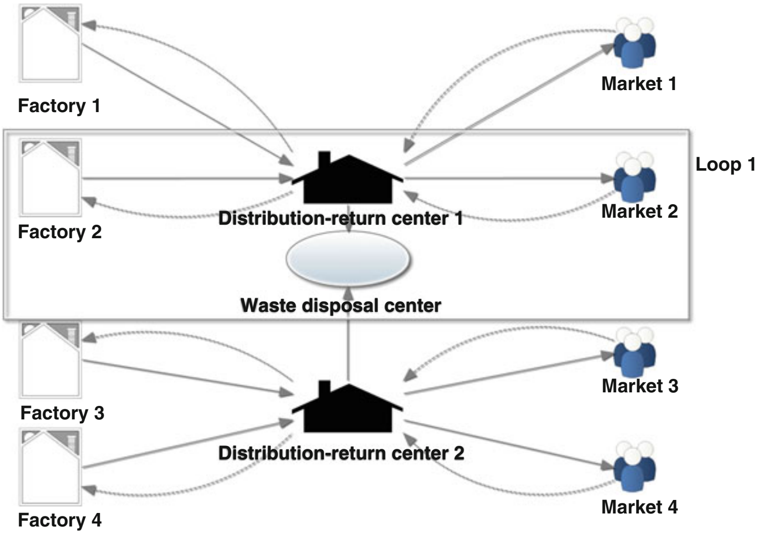


Fig. 98.1 The closed loop supply chain network

You can clearly see the structure of the CLSP network in Loop 1 in Fig. 98.1. The closed loop supply chain consists of these echelons: factories, distribution-return centers, markets and disposal centers. The forward supply chain begins with the production of the products. From factories, the finished products moved to the markets via distribution-return centers. In the reverse supply chain, returned products are collected and transhipped to the distribution-return centers, where the recycled products are inspected, consolidated and sorted into two kinds: the available one that sent to the factory for reproduction; the useless one that transported to the disposal center.

The assumptions are as follows:

(1) Only one product one period is considered;
(2) All the possible locations for distribution-return center can be identified;
(3) The demanded quantities of the product can be estimated because the order is placed in advance, and the returned quantities of the product are considered fuzzy random based on the fact that the customers may throw them away or use it as others. The availability of the recycled product is not sure considering the transportation and carry loss. The transportation cost and the transportation pollution is related to the distance between two facilities;
(4) The distribution-return center has capability limit;
(5) The location of the factories, markets and waste disposal centers has already been known;
(6) The storage of new products and recycled products is allowed in the distribution-return centers.

98.3 Modelling

In this section, a mathematical description for DRCLPCLSC, including the notations, the research problem and statement and a mathematical formulation is given.

98.3.1 Notations

In order to facilitate the problem description, the following notations are introduced.**Sets**

Ω: set of distribution-return center. $\Omega = \{1, 2, 3, \ldots, I\}$;
Ψ: set of factories, and $\Psi = \{1, 2, 3, \ldots, J\}$;
Φ: set of markets, and $\Phi = \{1, 2, 3, \ldots, K\}$;
Υ: set of waste disposal point, and $\Upsilon = \{1, 2, 3, \ldots, N\}$.

Indices and parameters

i: alternative location position of the distribution-return center, $i \in \Omega = \{1, 2, 3, \ldots, I\}$;
j: known position of the factory, $j \in \Psi = \{1, 2, 3, \ldots, J\}$;
k: known position of the market and $k \in \Phi = \{1, 2, 3, \ldots, K\}$;
n: known waste disposal point, $n \in \Upsilon = \{1, 2, 3, \ldots, N\}$;
U: the upper limit of the distribution-return center;
P_{ji}: product quantity from the factory j to distribution-return center i;
Q_{ik}: product quantity from distribution-return center i to the market k;
$\widetilde{\overline{a}}_{ki}$: returned product quantity from market k to distribution-return center i;
$\widetilde{\overline{b}}_{in}$: product quantity from distribution-return center i to waste disposal point n;
F_i^c: the fixed cost of the distribution-return center;
V_i^c: the variable cost of the distribution-return center dealing with unit new product;
RV_i^c: the variable cost of the distribution-return center triaging unit returned product;
α_{ij}^p: unit transportation cost between the distribution-return center i and factory j;
α_{ik}^d: unit transportation cost between the distribution-return center i and market k;
α_{in}^w: unit transportation cost between the distribution-return center i and waste disposal point n;
L_i: the capability of the distribution-return center i;
β_{ij}: unit transportation pollution between the distribution-return center i and factory j;

β_{ik}: unit transportation pollution between the distribution-return center i and market k;

β_{in}: unit transportation pollution between the distribution-return center i and waste disposal point n.

$\overline{\widetilde{C_{ij}^{p}}}$: unit transportation cost between the distribution-return center i and factory j.

$\overline{\widetilde{C_{ik}^{d}}}$: unit transportation cost between the distribution-return center i and market k.

$\overline{\widetilde{C_{in}^{w}}}$: unit transportation cost between the distribution-return center i and waste disposal point n.

D_k: the demand of the market k according to the order.

Decision variables

x_i: a binary variable indicating that whether point i is chosen. If point i is chosen, then $x_i = 1$; else, $x_i = 0$.

y_{ik}: indicates whether the market k is served by the distribution-return center i. If i is chosen, then $y_{ik} = 1$; else,$y_{ik} = 0$.

98.3.2 Model Formulation

(1) Objective Functions

In general, the decision makers focus on minimize the transportation cost. It is one of the most important part of cost, and it affect a lot in the daily life operation of the distribution-return center. The minimization objective can be described as

$$\begin{aligned}\min F^T =& \sum_{i=1}^{I}\sum_{j=1}^{J} C_{ij}^{p} P_{ji} + \sum_{i=1}^{I}\sum_{k=1}^{K} C_{ik}^{d}(Q_{ik} + \overline{\widetilde{a}}_{ki}) \\ &+ \sum_{i=1}^{I}\sum_{n=1}^{N} C_{in}^{w}\overline{\widetilde{b}}_{in} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{n=1}^{N} C_{ij}^{p}(\overline{\widetilde{a}}_{ki} - \overline{\widetilde{b}}_{in}),\end{aligned} \tag{98.1}$$

Besides the transportation cost, the fixed cost and the operation is also an important part of it. The objective is described as

$$\min F^D = \sum_{i=1}^{I} F_i^c X_i + \sum_{i=1}^{I}\sum_{j=1}^{J} V_i^c P_{ji} + \sum_{i=1}^{I}\sum_{k=1}^{K} RV_i^c \overline{\widetilde{a}}_{ki}. \tag{98.2}$$

The transportation pollution is also of great influence, reducing the environment pollution is also considered by the decider.

$$\min F^P = \sum_{i=1}^{I}\sum_{j=1}^{J}\beta_{ij}P_{ji} + \sum_{i=1}^{I}\sum_{k=1}^{K}\beta_{ik}(Q_{ik}+\tilde{\bar{a}}_{ki}) + \sum_{i=1}^{I}\sum_{n=1}^{N}\beta_{in}\tilde{\bar{b}}_{in} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{n=1}^{N}\beta_{ij}(\tilde{\bar{a}}_{ki}-\tilde{\bar{b}}_{in}). \tag{98.3}$$

(2) Constraints for the Leader

Note that the distribution-return center has its own capacity limit and it cannot services any goods beyond its capacity. Thus we need a capacity restriction. This constraint can be written as follows:

$$\sum_{k=1}^{K}\tilde{\bar{a}}_{ki} + \sum_{j=1}^{J}P_{ji} \le L_i \quad \forall i \in \Omega. \tag{98.4}$$

Considering the products in the market are all from the distribution-renter center, the recycled products are less than the product transported from factory to the distribution-return center And it can be described as follows:

$$\sum_{j=1}^{J}P_{ji} \ge \sum_{k=1}^{K}\tilde{\bar{a}}_{ki}. \tag{98.5}$$

The product provided to the market should at least meet the market demand.

$$\sum_{i=1}^{I}Q_{ik} \ge \sum_{k=1}^{K}D_k, \tag{98.6}$$

The distribution-return center should be at least one but no more than the upper limit.

$$1 \le \sum_{i=1}^{I}x_i \le U. \tag{98.7}$$

It should make sure that each market is served by one distribution-return center.

$$\sum_{i=1}^{I}y_{ik} = 1. \tag{98.8}$$

Since x_i and y_{ik} are binary variables, the following constraints are needed:

$$x_i = \{0, 1\}, \quad \forall i \in \Omega, \tag{98.9}$$

$$y_{ik} = \{0, 1\}, \quad \forall i \in \Omega, \quad \forall k \in \Phi. \tag{98.10}$$

(3) Global Model

From the formulation above, it can seen that the distribution-return center layout problem can be formulated using two objective functions. The aims are minimize the cost and pollution. In our model, we have considered all the costs involved in the distribution-return center layout and the pollution influence. Further, fuzzy random theory has been used to deal with the real world complex uncertainties which may assist in making more scientific decisions. Finally, we can derive the global model:

$$\min F^T = \sum_{i=1}^{I}\sum_{j=1}^{J} C_{ij}^p P_{ji} + \sum_{i=1}^{I}\sum_{k=1}^{K} C_{ik}^d (Q_{ik} + \tilde{\bar{a}}_{ki}) + \sum_{i=1}^{I}\sum_{n=1}^{N} C_{in}^w \tilde{\bar{b}}_{in} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{n=1}^{N} C_{ij}^p (\tilde{\bar{a}}_{ki} - \tilde{\bar{b}}_{in})$$

$$\min F^D = \sum_{i=1}^{I} F_i^c x_i + \sum_{i=1}^{I}\sum_{j=1}^{J} V_i^c P_{ji} + \sum_{i=1}^{I}\sum_{k=1}^{K} RV_i^c \tilde{\bar{a}}_{ki}$$

$$\min F^P = \sum_{i=1}^{I}\sum_{j=1}^{J} \beta_{ij} P_{ji} + \sum_{i=1}^{I}\sum_{k=1}^{K} \beta_{ik} (Q_{ik} + \tilde{\bar{a}}_{ki}) + \sum_{i=1}^{I}\sum_{n=1}^{N} \beta_{in} \tilde{\bar{b}}_{in} + \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{n=1}^{N} \beta_{ij} (\tilde{\bar{a}}_{ki} - \tilde{\bar{b}}_{in})$$

$$s.t. \begin{cases} \sum_{k=1}^{K} \tilde{\bar{a}}_{ki} + \sum_{j=1}^{J} P_{ji} \le L_i x_i \quad \forall i \in \Omega, \quad \forall j \in \Psi, \quad \forall k \in \Phi \\ \sum_{j=1}^{J} P_{ji} \ge \sum_{k=1}^{K} \tilde{\bar{a}}_{ki} \quad \forall i \in \Omega, \quad \forall j \in \Psi, \quad \forall k \in \Phi \\ \sum_{i=1}^{I} Q_{ik} \ge \sum_{k=1}^{K} D_k \quad \forall i \in \Omega, \quad \forall k \in \Phi \\ 1 \le \sum_{i=1}^{I} x_i \le U \quad \forall i \in \Omega \\ y_{ik} \le x_i \quad \forall i \in \Omega, \quad \forall k \in \Phi \\ \sum_{i=1}^{I} y_{ik} = 1 \quad \forall i \in \Omega, \quad \forall k \in \Phi \\ x_i = \{0, 1\} \quad \forall i \in \Omega \\ y_{ik} = \{0, 1\} \quad \forall i \in \Omega, \quad \forall k \in \Phi. \end{cases} \tag{98.11}$$

98.4 The Heuristic Algorithms Based on PSO

Particle swarm optimization (PSO) [4] is a recent evolutionary algorithm, which simulates social behaviors such as birds flocking, fish schooling to a certain place looking for good. PSO conducts searches to seek solutions throughout the feasible zone using a fixed population number of individuals, which are updated to achieve an optimal solution. The particles are characterized by their position and velocity, which are decided by its flying experiences or discoveries or these of their companions. They fly through the problem spaces following the current optimum particles to find the best solution between populations and the best solution for each population. PSO has been widely used in the real world to solve optimization problems, especially solving multi-objective optimal problems, so a heuristic algorithms based on PSO is applied to solve the proposed model.

Notations:

τ: iteration index, and $\tau = 1, 2, \ldots, T$;
d: dimension index, and $d = 1, 2, \ldots, D$;
l: particle index, and $l = 1, 2, \ldots, L$;
ω_τ: inertia weight in τth iteration;
$v_{ld}(\tau)$: velocity of the lth particle at the dth dimension in the τth iteration;
$p_d^l(\tau)$: position of the lth particle at the dth dimension in the τth iteration;
p_{ld}^{best}: personal best position;
p_{gd}^{best}: global best position;
c_p: personal best position acceleration constant;
c_g: global best position acceleration constant;
$P^{\max}$: maximum position value;
$P^{\min}$: minimum position value;
$r_{1,2}$: uniform distributed random number within [0,1].

The researchers usually update the position and velocity of each particle according to the following equation:

$$v_d^l(\tau+1) = \omega(\tau)v_d^l(\tau) + c_p r_1[p_{ld}^{\text{best}}(\tau) + p_d^l(\tau)] + c_g r_2[p_{gd}^{\text{best}}(\tau) - p_d^l(\tau)], \tag{98.12}$$

$$p_d^l(\tau) = p_d^l(\tau) + v_d^l(\tau+1). \tag{98.13}$$

The framework of the PSO to solve the DRCLPCLSC is presented in this part.

Step 1. Initialize L particles as a swarm: $l = 1, \ldots, L$, generate the position of the ith particle with integer random position x_l. The value can be $1, \ldots, N$, $P^{\max} = N$, $P^{\min} = 0$. There is more than one '0', and other value can be unequal.

Step 2. Decode particles into solutions: For lth particle, if $x_l = 0$ denotes that distribution-return center l does not exist at the location l.

Step 3. Check the feasibility of solutions: For $l = 1, \ldots, L$, if all the particles met the feasibility criterion, i.e. $\sum_{k=1}^{K} \tilde{\tilde{a}}_{ki} + \sum_{j=1}^{J} P_{ji} \leq L_i x_i$, then continue. Otherwise, return to Step 1.

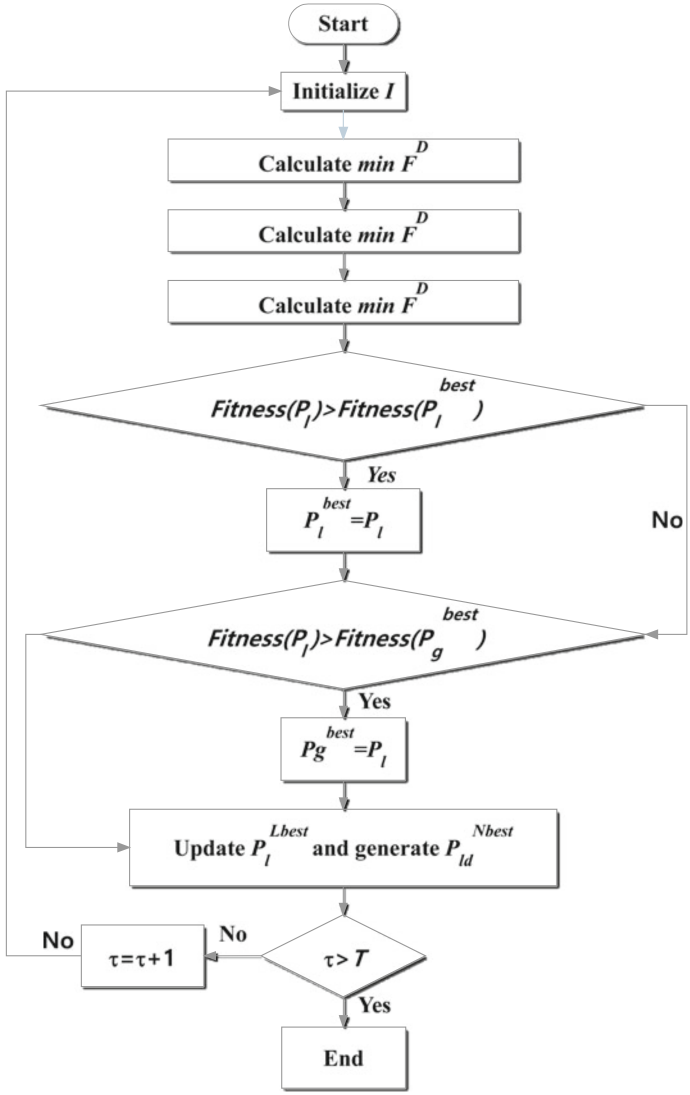


Fig. 98.2 The heuristic algorithms based on PSO

Step 4. Initialize the speed of each particle and personal best position: Let velocity $V_{lf} = [v_{l1}(1), v_{l2}(1), v_{l3}(1), \ldots, v_{lN}(1)]$, and the value is between 0 and 1. The initial p_{ld}^{best} is current position.

Step 5. Evaluate each of the particles: For $l = 1, 2, \ldots, L$, compute the performance measurement under every objective, and set the objective value as the fitness value $X_l(t)$, represented by $\text{Fitness}_l(X_l(t))$.

Step 6. If the stop criterion is met, i.e. $t = T$, stop. Otherwise, $t = t + 1$ and return to Step 4.

The algorithm can be seen more clearly from Fig. 98.2, which is the overall procedure for PSO.

98.5 Conclusion

In this paper, a multi-objective distribution-return center of closed-loop supply chain layout problem under fuzzy random environment has been discussed. For this problem, a new model is formulated. In this model, the decision maker seeks cost and pollution minimization and has constraints on flow, capability limits. To more accurately represent actual production situations, the return products and unavailable rate are considered to be fuzzy random variables. To solve this problem, a heuristic algorithms based on PSO is applied. The proposed model and method can be applied to decide the location of distribution-return center, which affects a lot in a closed-loop supply chain. To develop more suitable models, more constraints and more relationships should be considered. As for the uncertainties, more fuzzy random variables should be involved.

Acknowledgments This research was supported by NSFC (Grant No. 71401020), NPOPSS (Grant No. 14BGL055), HPOPSS (Grant No. HB15GL111) and Human Social Science for Universities of Hebei (Grant No. SD151011, Grant No. BJ2016057).

References

1. Dai Z, Zheng X (2015) Design of close-loop supply chain network under uncertainty using hybrid genetic algorithm: a fuzzy and chance-constrained programming model. Comput Ind Eng 88:444–457
2. Fallah H, Eskandari H, Pishvaee MS (2015) Competitive closed-loop supply chain network design under uncertainty. J Manufact Syst 37:649–661
3. Kaya O, Urek B (2016) A mixed integer nonlinear programming model and heuristic solutions for location, inventory and pricing decisions in a closed loop supply chain. Comput Oper Res 65:93–103
4. Kennedy J, Eberhart R (1995) Particle swarm optimization. In: Proceedings of IEEE international conference on neural networks, vol 4, pp 1942–1948. IEEE, New York
5. Khatami M, Mahootchi M, Farahani RZ (2015) Benders' decomposition for concurrent redesign of forward and closed-loop supply chain network with demand and return uncertainties. Transp Res Part E Logist Transp Rev 79:1–21
6. Soleimani H, Kannan G (2015) A hybrid particle swarm optimization and genetic algorithm for closed-loop supply chain network design in large-scale networks. Appl Math Model 39:3990–4012
7. Subulan K, Baykasoğlu A et al (2014) A case-oriented approach to a lead/acid battery closed-loop supply chain network design under risk and uncertainty. J Manufact Syst 37:340–361

8. Vahdani B, Mohammadi M (2015) A bi-objective interval-stochastic robust optimization model for designing closed loop supply chain network with multi-priority queuing system. Int J Product Econ 170:67–87
9. Xu J, Li Z (2012) Multi-objective dynamic construction site layout planning in fuzzy random environment. Autom Constr 27:155–169
10. Yang G, Ning S, Li Q (2009) Genetic local search for facility location-allocation problem in closed-loop supply chains. In: 2009 1st international conference on information science and engineering (ICISE), pp 4316–4319. IEEE, New York

Chapter 99
Research on Three-Level Supply Chain Coordination Based on Revenue Sharing Contract and Option Contract

Jiaojiao Cong and Hongchun Wang

Abstract Supply chain coordination is an important goal of supply chain management. Considering a three-level supply chain, which is consisting of a manufacturer, a distributor, and a seller, it studies the problem of the coordination of the three-level supply chain under the combination contracts. Distributor and seller will cooperate in the form of option contract, and distributor and manufacturer will cooperate in the form of revenue sharing contract. Firstly, the supply chain contract model under the assumption of risk neutral is established, so the optimal order quantity of supply chain is obtained and the coordination of the three-level supply chain is studied. Also, the relationship between the contract parameters is given when the supply chain can achieve coordination. Then, this paper introduces the risk factors, and establishes the new contract model under the consideration of the seller's risk seeking and the distributor's risk aversion. Finally, the relevant conclusions are proved by numerical examples.

Keywords Three-level supply chain · Revenue sharing contract · Option contract · Coordination

99.1 Introduction

In recent years, the researches on supply chain coordination are more and more common. Supply chain is a complex network, including seller, manufacturer and other members, and the market demand is random. These factors will affect the efficiency of supply chain operation. So it is very important to realize the supply chain coordination in order to improve the efficiency of supply chain. At present, a lot of literature can prove that the supply chain contracts can coordinate the complex relationship between the supply chain members. Therefore, the overall efficiency will be improved. The research on the coordination of supply chain contracts mainly has

---

J. Cong · H. Wang (✉)
Beijing University, Beijing 100044, People's Republic of China
e-mail: wanghongchun@bucea.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_99

the quantity discount contract, the buy-back contract, the revenue sharing contract and the option contract, and so on. For example, Sun [11] established the model of the profit distribution of the three echelon supply chain under the buy-back contract which is composed of the supplier, manufacturer and seller, then it determines the buy-back price and the seller's optimal order quantity under the condition of supply chain coordination; Zhang [14] studied the coordination of the three-level supply chain under the penalty contract and the revenue sharing contract, and it pointed out that the supply chain profits are improved under the combination contracts; Liu [6] studied the problem of coordinating the three-level supply chain under the combination contracts of the revenue sharing contract and the buy-back contract. Bai [1] studied a two-echelon supply chain system, and it is proved that revenue sharing contract and revenue and cost sharing contract can both lead to perfect coordination; Henry [4] used multiscale decision theory (MSDT) in the study of three-level supply chain; Pang [8] considered the coordination of the three-level supply chain who faces a stochastic and sales effort dependent demand under the revenue sharing contract; Pal [7] studied the coordination mechanisms in a competitive supply chain consisting of multiple retailers and a common supplier. Although there are a lot of researches on the coordination of supply chain, the research on the coordination of the three-level supply chain under the option contract is relatively rare.

In addition, it is worth noting that most studies on supply chain coordination are carried out under the assumption that the participants are risk neutral. However, in reality, because of the existence of individual subjective consciousness, decision makers' attitude is often different when they are at risk. Therefore, it has important theoretical value and practical significance where risk factors are introduced into the model. Some scholars have studied the problem. For example, Sang [9] studied the coordination problem of the three-level supply chain with risk preference under the revenue sharing contract by using the method of the expected return variance; He [3] studied the effect of risk preference on supply chain coordination under the buy-back contract; Shang [10] characterised the Pareto-optimal contracts for the two- and three-stage dual-channel supply chains, by developing and maximising system utility function related to risk preferences and negotiating power; Xu [13] proposed a new definition to the loss-averse newsvendor problem-legacy loss, and the optimal decisions are obtained; Du [2] studied the impacts of the risk preference and the decreasing value of strategic customers on the ordering quantity, the sale price and the total profit; Wang [12] studied a relief supply chain with option contract, and it analyzes the profit distribution taking into account the risk preference.

In this paper, we consider the three-level supply chain, which is composed of a single manufacturer, a single distributor and a single seller, and the market demand is random. First, seller and distributor sign the option contract, and the distributor and the manufacturer sign the revenue sharing contract, so the basic contract model is established, and the coordination of the three-level supply chain is studied. Then, risk factors are introduced into the model, and we assume that the seller is risk-seeking and distributor is risk-averse. So, the new contract model is established.

The rest of the paper is organized as follows. In Sect. 99.2, the basic model for option contract and revenue sharing contract is established. In Sect. 99.3, the supply chain contract model based on risk preference is analyzed. In Sect. 99.4, numerical examples are provided. In Sect. 99.5, conclusions are given.

99.2 Basic Model Description

99.2.1 Symbolic Description and Hypothesis

In the three-level supply chain consisting of a single manufacturer, a single distributor and a single seller, the market demand is random. Seller's product price is p; in the option contract signed by the seller and the distributor, the seller's option order quantity is q, the option price is w_0, the option execution price is w_e; the whole sale price that is given by manufacturer is w_{md}; the marginal cost of the seller, the distributor and the manufacturer respectively is $c_r c_d c_m$, so the total cost of supply chain is $c = c_r + c_d + c_m$; in the revenue sharing contract signed by the manufacturer and the distributor, the manufacturer can get $r(0 < r < 1)$ times earnings of the distributor; the loss cost of the seller, distributor and manufacturer respectively is $g_r g_d g_m$, so the total loss cost of supply chain is $g = g_r + g_d + g_m$. Random market demand is x, and the interval value is $[0, D]$ and $EX = \mu$; probability distribution of demand is $f(x)$; the distribution function of the demand is $F(x)$. It is assumed that the manufacturer, distributor and seller are risk neutral and completely rational, and the information of the three parties is fully shared. Expected sales volume: $s(q) = q - \int_0^q F(x)dx$. Expected amount of unmet need: $L(q) = \mu - s(q)$.

99.2.2 Supply Chain Contract Model

According to the above conditions, the supply chain's expected profit is:

$$\Pi(q) = ps(q) - cq - gL(q) = (p + g)s(q) - cq - g\mu.$$

Then,

$$\frac{\partial \Pi(q)}{\partial q} = (p + g)(1 - F(q)) - c = 0.$$

So, the optimal order quantity of supply chain is:

$$F(q^*) = \frac{p + g - c}{p + g}.$$

The seller's expected profit is:

$$\begin{aligned}\Pi_r &= ps(q) - w_e s(q) - w_0 q - c_r q - g_r L(q)\\ &= (p - w_e + g_r)s(q) - (w_0 + c_r)q - g_r u.\end{aligned}$$

Then,

$$\frac{\partial \Pi_r}{\partial q} = (p - w_e + g_r)[1 - F(q)] - (w_0 + c_r).$$

So, the optimal order quantity of seller is:

$$F(q_r^*) = \frac{p - w_e + g_r - w_0 - c_r}{p - w_e + g_r}.$$

The distributor's expected profit is:

$$\Pi_d = (1 - \gamma)(w_0 q + w_e s(q)) - w_{dm} q - c_d q - g_d L(q).$$

Then,

$$\frac{\partial \Pi_d}{\partial q} = (1 - \gamma)[w_0 + w_e(1 - F(q))] - w_{dm} - c_d + g_d(1 - F(q)).$$

So, the optimal order quantity of distributor is:

$$F(q_d^*) = \frac{(w_0 + w_e)(1 - \gamma) + g_d - w_{md} - c_d}{w_e(1 - \gamma) + g_d}.$$

The manufacturer's expected profit is:

$$\Pi_m = \gamma(w_0 q + w_e s(q)) + w_{dm} q - c_m q - g_m L(q).$$

Then,

$$\frac{\partial \Pi_m}{\partial q} = \gamma[w_0 + w_e(1 - F(q))] + w_{dm} - c_m + g_m(1 - F(q)).$$

So, the optimal production quantity of manufacturer is:

$$F(q_m^*) = \frac{\gamma(w_0 + w_e) + w_{dm} + g_m - c_m}{\gamma w_e + g_m}.$$

99.2.3 Analysis of Supply Chain Coordination Under Risk Neutral

Theorem 99.1 *In the three-level supply chain, it is composed of the manufacturer, the distributor and the seller.*

When the supply chain can achieve coordination under the combined contracts of revenue sharing contract and option contract, the contract parameters meet the following conditions:

$$\begin{aligned} w_0 &= p - w_e - c_r + g_r - \alpha(p - w_e + g_r), \\ w_{md} &= (1-\gamma)[(1-\alpha)(p+g_r) - c_r] + (1-\alpha)g_d - c_d. \end{aligned}$$

Proof In the three-level supply chain, the supply chain can achieve coordination, so $F(q_r^*) = F(q_d^*) = F(q_m^*) = F(q)$.

Namely,

$$\begin{aligned} \frac{p - w_e + g_r - w_0 - c_r}{p - w_e + g_r} &= \frac{(w_0 + w_e)(1-\gamma) + g_d - w_{md} - c_d}{w_e(1-\gamma) + g_d} \\ &= \frac{\gamma(w_0 + w_e) + w_{dm} + g_m - c_m}{\gamma w_e + g_m} \\ &= \frac{p + g - c}{p + g}. \end{aligned}$$

Here, it is assumed that $\dfrac{p+g-c}{p+g} = \alpha$.
Then, $\dfrac{p - w_e + g_r - w_0 - c_r}{p - w_e + g_r} = \alpha$,
so,

$$w_0 = p - w_e - c_r + g_r - \alpha(p - w_e + g_r), \tag{99.1}$$
$$\frac{(w_0 + w_e)(1-\gamma) + g_d - w_{md} - c_d}{w_e(1-\gamma) + g_d} = \alpha,$$

so, $w_{md} = (1-\gamma)(w_e + w_0) - c_d + g_d - \alpha[(1-\gamma)w_e + g_d]$.

It can be concluded by Eq. (99.1) that

$$w_{md} = (1-\gamma)[(1-\alpha)(p+g_r) - c_r] + (1-\alpha)g_d - c_d. \tag{99.2}$$

Then we can know that

$$\begin{aligned}
&\frac{\gamma(w_0+w_e)+w_{dm}+g_m-c_m}{\gamma w_e+g_m}\\
&=\frac{\gamma(p-w_e-c_r+g_r-\alpha(p-w_e+g_r)+w_e)}{\gamma w_e+g_m}\\
&\quad+\frac{(1-\gamma)[(1-\alpha)(p+g_r)-c_r]+(1-\alpha)g_d-c_d+g_m-c_m}{\gamma w_e+g_m}\\
&=\frac{\gamma(p+g_r-\alpha(p-w_e+g_r))+(1-\gamma)(1-\alpha)(p+g_r)-c+(1-\alpha)g_d+g_m}{\gamma w_e+g_m}\\
&=\frac{\gamma((1-\alpha)(p+g_r)+\alpha w_e)+(1-\gamma)(1-\alpha)(p+g_r)-c+(1-\alpha)g_d+g_m}{\gamma w_e+g_m}\\
&=\frac{\gamma\alpha w_e+p+g-c-\alpha(p+g_r+g_d)}{\gamma w_e+g_m}\\
&=\frac{\gamma\alpha w_e+\alpha(p+g)-\alpha(p+g_r+g_d)}{\gamma w_e+g_m}\\
&=\alpha.
\end{aligned}$$

So, when the contract parameters satisfy the conditions (99.1) and (99.2), the supply chain can be coordinated.

99.3 Supply Chain Contract Model Based on Risk Preference

In the three-level supply chain system, risk factors are introduced. Here we assume that the seller is risk-seeking and distributor is risk-averse. In this paper, we use the method of conditional value at risk (CVaR) [5] to describe the risk preference of the seller and the distributor. When the risk-seeking level is, the conditional value at risk is:

$$CVaR\pi(q)=E(\pi|\pi\geq\pi_\theta.)=\frac{1}{1-\theta}\int\limits_{\pi\geq\pi_\theta}\pi f(\pi)d\pi,$$

$f(\pi)$ is the probability density function of the random variable π. When $\theta=0$, it indicates risk neutral.

When the risk aversion level is λ, the conditional value at risk is:

$$CVaR\pi(q)=E(\pi|\pi\leq\pi_\lambda.)=\frac{1}{\lambda}\int\limits_{\pi\leq\pi_\lambda}\pi f(\pi)d\pi,$$

$f(\pi)$ is the probability density function of the random variable π. When $\lambda=1$, it indicates risk neutral.

Therefore, the seller's risk seeking value is:

$$
\begin{aligned}
CVaR\pi_r(q) = & \frac{1}{1-\theta}\left\{ \int_{F^{-1}(\theta)}^{q} [(p-w_e)x - w_0 q - c_r q]dF(x) \right. \\
& \left. + \int_{q}^{D} [(p - w_0 - w_e - c_r)q - g_r(x-q)]dF(x) \right\}.
\end{aligned}
$$

Then,

$$
\begin{aligned}
\frac{\partial CVaR\pi_r(q)}{\partial q} = & \frac{1}{1-\theta}\{[-(w_0 + c_r)(F(q) - \theta)] \\
& - (p - w_e - w_0 - c_r + g_r)(F(q) - 1)\}.
\end{aligned}
$$

So, the optimal order quantity of the seller with risk seeking is:

$$
F(q_{r1}^*) = \frac{p - w_e + g_r - w_0 - c_r + \theta(w_0 + c_r)}{p - w_e + g_r}.
$$

The distributor's risk aversion value is:

$$
\begin{aligned}
CVaR\pi_d(q) = & \frac{1}{\lambda}\left\{ \int_0^q [(1-\gamma)(w_0 q + w_e x) - c_d q - w_{md} q]dF(x) \right. \\
& \left. + \int_q^{F^{-1}(\lambda)} [(1-\gamma)(w_0 q + w_e q) - c_d q - w_{md} q - g_d(x-q)]dF(x) \right\}.
\end{aligned}
$$

Then,

$$
\begin{aligned}
\frac{\partial CVaR\pi_d(q)}{\partial q} = & \frac{1}{\lambda}\Big\{[(1-\gamma)w_0 - c_d - w_{md}]F(q) \\
& - [(1-\gamma)(w_0 + w_e) - c_d - w_{md} + g_d][F(q) - \lambda]\Big\}.
\end{aligned}
$$

So, the optimal order quantity of the distributor with risk aversion is:

$$
F(q_{d1}^*) = \frac{(w_0 + w_e)(1-\gamma) + g_d - w_{md} - c_d}{w_e(1-\gamma) + g_d}\lambda.
$$

99.3.1 Analysis of Supply Chain Coordination Under Risk Preference

Theorem 99.2 *In the three-level supply chain, it is composed of the risk neutral manufacturer, the risk-averse distributor and the risk-seeking seller.*

When the supply chain can achieve coordination under the combined contracts of revenue sharing contract and option contract, the contract parameters meet the following conditions:

$$\begin{aligned}
&w_0 = \frac{1}{1-\theta}[p - w_e - c_r + g_r + \theta c_r - \alpha(p - w_e + g_r)],\\
&w_{md} = (1-\gamma)(w_0 + w_e) + g_d - c_d - \frac{\alpha}{\lambda}[(1-\gamma)w_e + g_d],\\
&\lambda(\alpha - \theta) - \alpha(1-\theta)(1-\gamma-\gamma\lambda) = 0,\\
&\frac{1-\alpha}{1-\theta}\theta(p + g_r) + (\alpha - \frac{\alpha}{\lambda})g_d = 0.
\end{aligned}$$

Proof In the three-level supply chain, the supply chain with risk preference can achieve coordination, so $F(q_{r1}^*) = F(q_{d1}^*) = F(q_m^*) = F(q)$.

Namely,

$$\begin{aligned}
&\frac{p - w_e + g_r - w_0 - c_r + \theta(w_0 + c_r)}{p - w_e + g_r}\\
&= \frac{(w_0 + w_e)(1-\gamma) + g_d - w_{md} - c_d}{w_e(1-\gamma) + g_d}\lambda = \frac{\gamma(w_0 + w_e) + w_{dm} + g_m - c_m}{\gamma w_e + g_m}\\
&= \frac{p + g - c}{p + g}.
\end{aligned}$$

Here, it is assumed that $\frac{p + g - c}{p + g} = \alpha$.

Then, $\frac{p - w_e + g_r - w_0 - c_r + \theta(w_0 + c_r)}{p - w_e + g_r} = \alpha$.

So, $w_0 = \frac{1}{1-\theta}[p - w_e - c_r + g_r + \theta c_r - \alpha(p - w_e + g_r)]$,

$$\frac{(w_0 + w_e)(1-\gamma) + g_d - w_{md} - c_d}{w_e(1-\gamma) + g_d}\lambda = \alpha.$$

So, $w_{md} = (1-\gamma)(w_0 + w_e) + g_d - c_d - \frac{\alpha}{\lambda}[(1-\gamma)w_e + g_d]$.

Then we can know that

$$\begin{aligned}&\frac{\gamma(w_0+w_e)+w_{dm}+g_m-c_m}{\gamma w_e+g_m}\\&=\frac{\gamma(\frac{1}{1-\theta}[p-w_e-c_r+g_r+\theta c_r-\alpha(p-w_e+g_r)]+w_e)}{\gamma w_e+g_m}\\&\quad+\frac{(1-\gamma)(w_0+w_e)+g_d-c_d-\frac{\alpha}{\lambda}[(1-\gamma)w_e+g_d]+g_m-c_m}{\gamma w_e+g_m}.\end{aligned}$$

Simplify, it can get that

$$\begin{aligned}&\frac{\gamma(w_0+w_e)+w_{dm}+g_m-c_m}{\gamma w_e+g_m}\\&=\frac{(1-\frac{\alpha(1-\gamma)}{\lambda}-\frac{1-\alpha}{1-\theta})w_e+p+g-c+\frac{\theta-\alpha}{1-\theta}(p+g_r)-\frac{\alpha}{\lambda}g_d}{\gamma w_e+g_m}\\&=\frac{(1-\frac{\alpha(1-\gamma)}{\lambda}-\frac{1-\alpha}{1-\theta})w_e+\alpha g_m+(\alpha+\frac{\theta-\alpha}{1-\theta})(p+g_r)+(\alpha-\frac{\alpha}{\lambda})g_d}{\gamma w_e+g_m}.\end{aligned}$$

When the supply chain can achieve coordination, the optimal production quantity of manufacturer should meet the following condition:

$$\frac{\gamma(w_0+w_e)+w_{dm}+g_m-c_m}{\gamma w_e+g_m}=\alpha.$$

So, $1-\frac{\alpha(1-\gamma)}{\lambda}-\frac{1-\alpha}{1-\theta}=\alpha\gamma$. Simplify, $\lambda(\alpha-\theta)-\alpha(1-\theta)(1-\gamma-\gamma\lambda)=0$.

And $(\alpha+\frac{\theta-\alpha}{1-\theta})(p+g_r)+(\alpha-\frac{\alpha}{\lambda})g_d=0$

99.4 Numerical Examples

In order to further explain the coordination of the three-level supply chain, this paper verifies the relevant conclusions by numerical analysis. Seller's product price is $p=230$; the marginal cost of the distributor, the distributor and the manufacturer respectively is $c_r=10$, $c_d=20$, $c_m=25$; the total cost of supply chain is $c=c_r+c_d+c_m=55$; $\lambda=0.2$; the loss cost of the seller, distributor and manufacturer respectively is $g_r=6$, $g_d=5$, $g_m=4$; the total loss cost of supply chain is $g=g_r+g_d+g_m=15$. Random market demand x is uniformly distributed: $x\sim U[0,400]$; probability distribution of demand $f(x)=\frac{1}{400}$; The distribution function of the demand $F(x)=\frac{x}{400}$. The optimal order quantity of supply chain $q*=312$, so the supply chain's expected profit is 26390. It can be seen from the

Table 99.1, the seller's expected profits will increase with the increase of the option price (or the decrease of the option execution price); the expected profits of the distributor will decrease with the increase of the wholesale price w_{md}, and will increase with the decrease of profit distribution ratio γ; the manufacturer's expected profits will increase with the increase of the wholesale price w_{md}, and will decrease with the decrease of profit distribution ratio γ. In addition, distributor's profits and manufacturer's profits will reduce with the increase of the option price (or the decrease of the option execution price). It can be seen from the Table 99.2, when the distributor is risk neutral, the seller's order quantity will increase with the increase of the degree of risk seeking, and distributor's order quantity will not change much; when the seller is risk neutral, the distributor's order quantity will decrease with the increase of the degree of risk aversion, and the order quantity of the seller will not change; when the seller is risk-seeking and the distributor is risk-averse, the order quantity of the seller and the distributor will increase with the increase of the degree of the risk-seeking and risk aversion.

Table 99.1 Profit distribution of supply chain members under risk neutral

w_0	w_e	w_{md}	g	The seller's expected profit	The distributor's expected profit	The manufacturer's expected profit
20	100	13	0.2	15280	9846	1264
20	100	14	0.2	15280	9534	1576
20	100	15	0.2	15280	9222	1888
25	77	15	0.2	18090	6974	1326
30	54	15	0.2	20900	4726	764
30	54	15	0.1	20900	6688	−1198
30	54	15	0.05	20900	7669	−2179

Table 99.2 Order quantity of seller and distributor under risk preferences ($\gamma = 0.2$)

w_0	θ	w_e	λ	w_{md}	The optimal order quantity of seller	The optimal order quantity of distributor
20	0.5	140	1	19	338	321.37
20	0.6	145	1	20	347	320.66
20	0.7	150	1	21	358	320
30	0	54	0.9	9	312	323
30	0	54	0.8	4	312	320
30	0.1	75	0.9	11	310	321
30	0.2	85	0.85	8	315	321.37
30	0.4	105	0.8	4	327	320

99.5 Conclusion

At present, the research on the coordination of the three-level supply chain under the combination contracts is less, and most of the studies have neglected the existence of the risk. In reality, the risk is inevitable, and it is one of the factors that can not be ignored when decision makers make decisions. So it is necessary to introduce risk factors into the model. In this paper, we study the coordination problem of three-level supply chain, which is composed of a risk neutral manufacturer, a risk-averse distributor and a risk-seeking seller. Firstly, it establishes the risk neutral supply chain contract model, and the optimal order quantity of supply chain is given. It also provides the conditions for coordination of the three-level supply chain with risk neutral. Then, the risk factors are introduced into the model, and the new model of the combination contracts is established. And it gives the relationship between the option price, the option execution price, the seller's risk seeking, the wholesale price of the manufacturer and the risk aversion of the distributor.

Acknowledgments This work was supported by the National Natural Science Foundation of China under Grant No. 61203148. No. 13 JGC 096. No. 61472027.

References

1. Bai QG, Xu XH et al (2015) A two-echelon supply chain coordination for deteriorating item with a multi-variable continuous demand function. Int J Syst Sci Oper Logist 2(1):49–62
2. Du J, Zhang J, Hua G (2015) Pricing and inventory management in the presence of strategic customers with risk preference and decreasing value. Int J Product Econ 164:160–166
3. He X (2014) The research on the effect member risk preference to supply chain coordination mechanism. Logist Eng Manag 36:81–82 (in Chinese)
4. Henry A, Wernz C (2015) A multiscale decision theory analysis for revenue sharing in three-stage supply chains. Ann Oper Res 226(1):277–300
5. Jian H (2013) Supply chain contracts and its experimental study based on risk and fairness preference. PhD thesis, Central South University, Changsha (in Chinese)
6. Liu G (2013) Risk analysis on three-level supply chains coordinated by a revenue sharing contract and a buyback contract. Value Eng 35:013
7. Pal B, Sana SS, Chaudhuri K (2015) Coordination contracts for competitive two-echelon supply chain with price and promotional effort sensitive non-linear demand. Int J Syst Sci Oper Logist 2(2):113–124
8. Pang Q, Chen Y, Hu Y (2014) Coordinating three-level supply chain by revenue-sharing contract with sales effort dependent demand. Discrete Dynamics in Nature and Society 2014
9. Sj Sang, Jx Wang, Yang Y (2008) Study on revenue sharing contract mechanism in three-stage supply chain with risk preference. Ind Eng Manag 4:004
10. Shang W, Yang L (2015) Contract negotiation and risk preferences in dual-channel supply chain coordination. Int J Product Res (ahead-of-print):1–20
11. Sun Z, Chang Q, Lu Y (2013) Research on the profit distribution in the three-level supply chain based on buy-back contract. J Qingdao Univ Sci Technol (Soc Sci) 3:018

12. Wang X, Li F et al (2015) Pre-purchasing with option contract and coordination in a relief supply chain. Int J Product Econ
13. Xu X, Meng Z et al (2015) Optimal decisions for the loss-averse newsvendor problem under cvar. Int J Product Econ 164:146–159
14. Zhang W, Guo L, Guo F (2005) Research on coordination policyin a three level supply chain based on punishment and revenue sharing contract. Forecasting 34:76–80

Chapter 100
Exploration on the Path of Green Production Innovation in SMEs from the Perspective of Supply Chain

Hua Wen

Abstract The growing social and regulatory concern for the environment is leading an increasing number of small and medium-sized enterprises (SMEs) to considering 'green' issues as a major source of strategic change. Green production innovation is not only technology innovation but also the innovation of product, process and management, which is a comprehensive, complicated process. Meanwhile, Green production innovation is not only a single issue for SMEs, but also involves all stakeholders of SMEs. This paper discusses the drivers to support SMEs in green production innovation from the view of supply chain, and the every link in the supply chain will become the entry point and moment for SMEs in green production innovation.

Keywords Green production innovation · Supply chain · Small to medium sized enterprise · Innovation

100.1 Introduction

According to *National Economic and Social Development Statistical Bulletin* 2014 issued by National Bureau of Statistics of China [9], the gross domestic product (GDP) of China reaches 63.6463 trillion Yuan. According to the all types of markets data in February 2015 released by State Administration of Industry and Commerce of China [8], by the end of February 2015, there are 18,714,900 enterprises, 50,738,600 individual businesses and 1,337,400 farmer specialized cooperatives in China. According to the latest *Provisional Regulations of Small and Medium-sized Enterprises*, by the end of 2014, there are about 43,000,000 SMEs. Classified by

H. Wen (✉)
School of Economics and Management, Chengdu University, Chengdu 610000, People's Republic of China
e-mail: 846937934@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_100

market entity, SMEs account for over 99.3 % of the total number of market entity and 55.6 % of GDP in the country. The export volume of SMEs account for 62.3 % of the total nation export, bringing over 75 % urban employment opportunities and making up for 46.2 % of the total commercial and industrial tax payment. The newly added industrial output value of SMEs account for 74.7 % and the sales of SMEs is about 58.9 % of social sales. The number and capital of enterprises and individuals rise at same pace.

However, except for contributions to economy, SMEs have apparent negative effect to environment. To meet the expectations and requirements of social and economy sustainable development, SME administrators are encouraged to covert from inactive and passive response to active and prospective business behaviors on environment issues.

With the ever-increased environmental and resource pressure brought by the economic development, more and more enterprises put ecological efficiency and green issue as the priority of strategy changing during business process. Consideration of environment issues in business strategy is grounded on the change of society cognition, increase of competition pressure and enforcement of policy measures. Society, government and enterprise administrators and organizational stake holders (customers and employees, etc.) are increasingly aware that the consumptions of enterprise operating activities, such as mode of production, resource utilization and waste disposal, have impact on natural resources. For enterprise development strategy of SMEs, introduction of environmental factors, advocate of green production and improvement of the eco-efficiency are faced up with severe challenges, which comprise:

(1) The environmental management is multi-dimensional. Green operation usually means investment of different technologies which are far beyond the traditional enterprise technology.
(2) Environmental planning involves broader range. Environmental planning covers all the departments of organization management system, more broadly, it involves the whole supply chain, including suppliers, vendors, customers, end users and other non-traditional stakeholders.
(3) Environmental planning requires for fund support.

Limited by self-features, SMEs have operation weakness, such as short-term behavior of operation and production, shortage of funds and talents, weak capability of connection to society public sectors, competitors, logistic providers and other nontraditional stakeholders, which are the obstacles of carrying out green operation. Besides, enterprises administrators have the mindset that since SMEs are small in scale, weak in ability, have little impact on environment and receive less attention from governments and society, therefore environmental friendly activities have little contribution and consequently consideration of environment in enterprise operation is relatively passive. The thesis is aimed at exploring green paths in SMEs.

100.2 Innovation Issue

100.2.1 The Concept of Innovation

In 1934, Schumpeter firstly raised the concept of innovation. Combining innovation with economic development, he defined innovation as recombination of production resource. Innovation contains five special conditions: new product introduction, new production methods, new market exploitation, access to new supplying resources and new operating methods.

Since then, the concept of innovation has been enriched and developed. Innovation is no longer considered as the result of individual activity. Instead, innovation comprises technology and organization innovation. Technology innovation means product innovation (product change and new product commercialization) and production process innovation (manufacturing process change or access to new facility) which is more directly connected with enterprises' main activities; management and system innovation (administrative management agency, procurement commercialization/market and so on) is based on the changes of corporate structuring and administrative procedure, which is the innovation on management activities [6].

The concept of innovation comprises the following properties:

- A problem-solution process
- A interaction process involved inter-enterprise relationships
- A diversified learning process
- An invisible and visible knowledge exchange process

Innovation has evolved from the point of technology reform to the point of social networks [1], from information to knowledge. Knowledge-based innovation requires not only all kinds of knowledge but also a combination of knowledge from plenty of participators (manufacturers, suppliers, vendors, customers and other stakeholders). Continuous improvement is evolving into continuous innovation.

Innovation changes are variable. They can be the slight changes of existing products, process or the management that focus on all aspects of improvement, which are the so called incremental innovation; they also can be the breakthrough changes of products, process or management that obsolete the less competitive enterprises in terms of new design and technology, which are called radical innovation. The most prominent issues of innovation include: radical innovation, incremental innovation, product innovation, process innovation, administration innovation and technology innovation [2].

100.2.2 Product Innovation and Process Innovation

Innovation has many categories, among which the most two popular ones are product innovation and process innovation that belong to the enterprise technology innovation. The activity essence reflected by production innovation is that from concept to product marketization, the final product and service are changed for the purpose of providing new output and service to benefit the customers; the essence of process innovation is reflected in the method of producing the final product, including new tool, new facility and understanding of input and output efficiency as well as the employment of production and service operation. The process innovation especially needs to improve production efficiency, product quality and product reliability to raise customer value. Product innovation changes product and service provided by enterprises, while process innovation changes organizing production and methods to spread products and service. Product innovation has obvious market attention and customer-driven factors, while process innovation focuses on internal attention and skill improvement of product and service marketization; product innovation embodies product difference or product quality improvement, while process innovation tends to reflect production efficiency and effectiveness, which leads to decline in production cost. Both of product innovation and process innovation show significant strategic advantages.

In the product life cycle, product innovation and process innovation interact with each other. In different product life stages, the proportions of product and process innovation are obviously different [5].

According to different business strategies, support of product innovation and process innovation are different. Differentiation strategy emphasized excellent product performance. Product innovation contributes to improving product quality, therefore it greatly support differentiation strategy. On the contrary, low-cost strategy gets more supports from process innovation. Generally, process innovation contributes to improve efficiency and reduce cost. When a product or industry becomes mature, more enterprises will alter business strategy and change focus from product innovation to process innovation.

No matter product innovation or process innovation, both are innovation activities at enterprise level.

100.3 SME Green Production Innovation

100.3.1 SME Innovation

On enterprise innovation, there are two different arguments of demonstrating the relationship between enterprise scale and innovation activity. One argument illustrates that SMEs are more prone to be innovative. Due to its properties, SMEs can quickly respond to environment change and convert decisions accordingly. With less bureaucratic inertia and more flexible structure, SMEs can adapt and improve better, at the same time, accept and perform changes with less difficulty. Another argument holds that large enterprises are more innovative because they boast better fiscal and technology capability. Economies of scale share innovation failure risk and shoulder innovation cost. Therefore, large enterprises have capability to establish and maintain advanced equipment, have fund to employ professional experienced technicians, have ability to raise fund to stimulate innovation. Both of the above two arguments are supported with evidences. Seen from the result of systematic quantitative analysis, SMEs and innovation have significant correlation in statistics [2]. However, indicated by the R&D expenditure statistical data during 2010–2014 in China [9], the passion and investment for R&D in SMEs are unsatisfactory.

Research statistics show that SMEs tend to spend more resources on new products rather than new process [3]. This is because product innovation is considered as the access to market and receive fast output, thus get more reward. On the contrary, large enterprises benefit more from process innovation due to their advantages in utilizing existing market innovation. Process innovation can broadly influence the output of enterprises. Efficient process can reduce the marginal cost of production, thus enterprises take advantage from apportionment of innovation cost.

100.3.2 SME Innovation Obstacles

The researches of Mohen showed that innovation obstacles faced up by enterprises are cost, regulation restriction, human resource, organization culture, information flow and government policy, especially the SMEs are under such restrictions because their resource foundation are limited [7]. Without the regard to the controversy of innovation definition, successful innovation requires for the support of management layer and guarantee of resources. As shown in the Fig. 100.1, innovation obstacles come from interior and exterior enterprise, which hinder product, process and management innovations in enterprises.

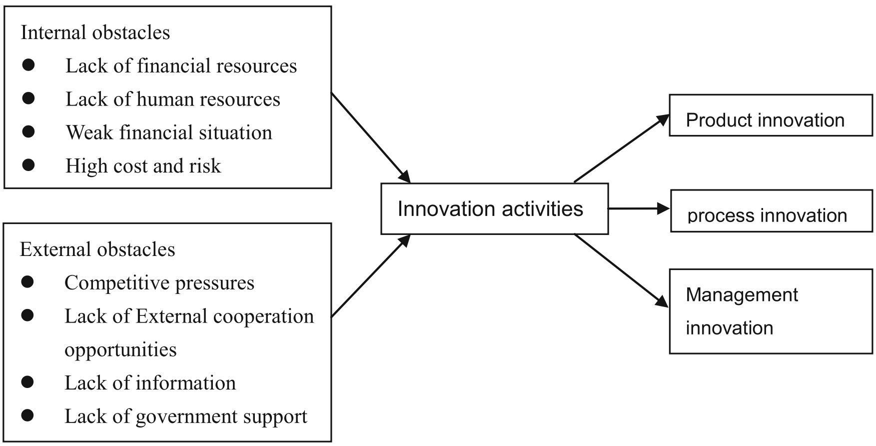


Fig. 100.1 Innovation obstacles

Internal obstacles are related to enterprise internal factors. To SMEs, such obstacles are relatively difficult to conquer and have negative effect to innovation activities; External obstacles are related to enterprise external factors and have relatively high operation risk.

Financial resource is regarded as the most significant influential factor; however, the uncertainty and high cost of innovation affect the investment aspiration. Managers of enterprises and investors are always influenced by the investment on innovation and risk aversion, and SMEs are especially affected due to limited financial resource. As a result of weak management in SMEs, problems such as weak communication, weak human resource practice and lack of top management commitment imply that organization culture does not accept risk brought by innovation. Meanwhile, it means that enterprise innovation is not supported, which is a notable factor of hindering innovation in SMEs. The operation of innovation, especially process and management innovation, require for commitment and efforts from employees because innovation will break existing workflow and procedures. One of the reasons for innovation obstacles is that employees are with weak working skills and inadequate training, however, it usually happens in SMEs.

External competitive pressure pushes enterprises to explore more potential to innovate for survival. The competitive pressure from buyer power appeared to be directly related to firms' intention to product innovation to prefer to avoid price wars and differentiate their product for SMEs apparently. The competitive pressure from supplier power formed association with the firms' intention to invest in process innovation [4]. SMEs need to adapt to such behavior to become independent. Lack of external information is another obstacle for SMEs' innovation. Information related to external environment of enterprise such as market opportunities, technology reform, government policy will affect administrators' innovation strategy, even though external environmental factors have negative impact in more situations. Information related to technology, market and government policies will reinforce the importance and advantages of innovation.

Except for resistance of objective factors, green innovation is also faced up with subjective resistance.

(1) Most SME managers have not realized their business activities have huge adverse impact. This is because SMEs are small in scale and single enterprise has unremarkable influence on environment, besides, decentralized operation, high monitoring cost, inadequate control slack the attitude of enterprise mangers towards environmental factors.
(2) A lack of convincing business cases which bring confidence to gain profit from green production. Environment management has long been considered as the secondary factor compared with core business activity. Resource-limited SMEs need more confidence support to invest on environment which is not closely related to profit.
(3) SME managers are usually unwilling to change behaviors. Because they are lack of resource as well as consciousness, especially these changes happen in investing on non-core business or process.

100.4 Green Production Innovation Efforts Made by SMEs

The sustainable development in economy and society is an irresistible trend. Enterprises, no matter large or small and medium-sized ones, are responsible to make efforts on good production and living circumstance. In fact, the government, enterprises and other institutions have made great efforts on enterprise green production innovation.

100.4.1 Policy Efforts

Firstly, production subsidy indicates the production activities of SMEs get support from governments. The support is significantly correlated to SME patent output. Production subsidy increases external funds sources and plays the role of supporting SME innovation.

Secondly, legal protections guarantee SME innovation operation and implementation. For example, Intellectual Property Law protects innovation achievements and therefore enterprises are willing to increase investment in R&D, improve product varieties, quality and efficiency. UK's department for Business, Enterprise, and Regulatory Reform has treated SME innovation as a crucial area of action, through policies such as advice on intellectual property and greater access to R&D grants and to public procurement opportunities for small businesses. Laws and regulations related to financial markets, labor markets, technology markets, information markets and equity markets guarantee the development of factor market, therefore, SMEs can organize and utilize innovation resources more easier. All levels of government construct industrial cluster where talent exchange, tax preference, information sharing, logistics and storage resources sharing are provided, stimulating the technical convergence across industries. Besides, SME innovation fund is found and resources are strengthened.

Thirdly, relevant policies are issued to improve SME environmental consciousness and action motivation. Government has formulated laws and regulations, besides, state council, ministers and commissions, and local governments have issued related environment protection regulations, moreover, law enforcement is strengthening. What's more, by methods such as pollution charge, emissions trading and discharge permit system stimulate the eco-tech innovation in SMEs; resolutely obsolete backward technology and productivity, strictly fight rule-breaking and illegal excessive emission, thus stimulate enterprises convert from traditional technology innovation to ecology innovation.

Even though our policy is updated and completed, the environment problem is more and more severe. While stimulating economic development and opening up, we also issue environment policies, but the control effect is unsatisfactory because there is huge gap between environment disruption and protection goal. There exist problems in policy making, implementation and shortage of supervision of enterprise behaviors is one of the reasons.

100.4.2 SME Management Efforts

SMEs in our country are distributed among each industry and many emerging enterprises adopt more effective technology since their foundation. Compared with large enterprises, SMEs are more flexible, quick-respond, sensitive, directly decided and therefore are able to capture more opportunities in green industry.

In 2001, since China joined WTO, the SMEs have benefited from the booming commercial export. Under global economic and law environment, restrictions such as green barrier, more strict foreign environmental standards (noises standard, antipollution standard, electromagnetic radiation standard and so on), system certification requirements (ISO14000, ISO9000, SA8000, WRAP, BSCI and so on), product certification requirements (depending on different products and export targets), greatly improve SME management and force SMEs to adopt environment-friendly operation mode. In 2014, the export volume of SMEs account for over 62.3 % of the total volume.

In April 2012, the first green SME influence report in our country was released and small-medium green enterprise models were selected for green business mode experience. The report pointed out that over the past three years, renewable energy, the fields of energy saving, pollutant prevention and control, and waste management industry have developed very fast with the respective pre-tax growth reached 96.7, 80.1, 202.1 %.

Some supporting agencies and industry association for SME suggest on industry, science, technology and innovation policies, offer consultation on investment promotion, enterprise management and quality management, and extend new and more environmental business practice, technology and cleaner production and enterprise responsibility.

100.5 Green Production Innovation Impetus

Despite of properties and current environment such as limited fund, lack of relevant talents, small scale, low level management and weak ability to take risk of innovation as well as lack of policy-type support and financial channels, SMEs are still faced up with pressure of ecology efficiency and need to make efforts on green production innovation by combining production and product properties in routine production and operation activities. Such efforts should be made on end products as well as the whole operation process. In most cases, SMEs seldom clearly classify innovation as “green”, because green innovation is not clear itself, on the contrary, is concealed under the demands of direct downstream immediate customers. Even

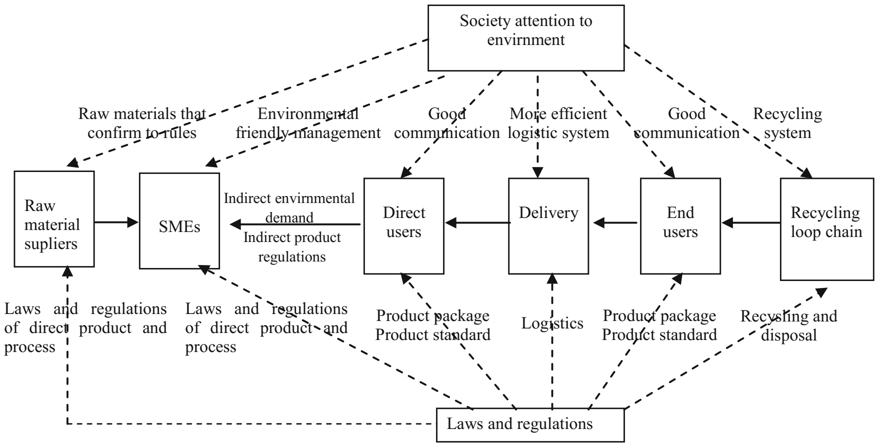


Fig. 100.2 Green innovation impetus in SMEs from the perspective of supply chain

though the end users seem have little attention to environment issues but more attention on product quality, cost price than ecology efficiency, the change of customer demands requires changes of logistics, operation, material consumption accordingly, thus alter the enterprise strategic orientation. In the long run, green innovation is of great importance to survival of SMEs. Therefore, SMEs need to transform the green innovation to development opportunities. As shown in Fig. 100.2, Green innovation impetus in SMEs from the perspective of supply chain.

Green production innovation (though many enterprises have not defined it as green innovation) is the inevitable challenges that confront enterprises especially SMEs:

(1) Impetus of enterprise green innovation comes from demand of future market. Green product innovation is a complex process as it is not only product innovation but also process innovation. Therefore, green innovation activity is not isolated to enterprise strategies.
(2) Require not only key competence and technology, but also competence to percept and discover innovation impetus in the whole supply chain. Besides, choose and develop the platform for eco-efficient materials, products, structure and operating.
(3) Require basic supporting structure to develop and implement green production innovation. Green production innovation covers a wide range, including process innovation, product innovation and management innovation, and involves non-traditional stakeholders. The basic support contains knowledge network and logistics network.
(4) Establish green image. Green innovation reputation is the result of initial technology investment and other green strategy selection. It is not simple technology innovation, instead, successful green innovation is not only based on technology and product but also based on green choice consistent in all aspects in SMEs.

100.6 Conclusion

Green production innovation in SMEs advocates that enterprises should continuously improve production efficiency and environment protection performance despite of industries, scale and locations. To achieve this, enterprises should take practical actions to improve resource utilization efficiency, obsolete hazardous substances, increase reusable energy utilization proportion, improve occupational health and safety, shoulder more producer responsibility, decrease risk on environment, atmosphere and human. Production environment performance for SMEs is a complex management work. On one hand, it requires SMEs to review product life circle from an updated perspective, covering the whole process of raw material access, manufacture, distribution, utilization and recycle/reuse. On another hand, it requires SMEs to undertake the reform towards environmental friendly society that meet the expectations of stakeholders. Therefore, society attention and laws and regulation are crucial factors to carry out environment planning in whole supply chain. Every link in supply chain can be the breakthrough point of green innovation. The future research will make further exploration on green production innovation based on supply chain.

References

1. Ahuja G (2000) Collaboration networks, structural holes, and innovation: a longitudinal study. Adm Sci Quart 45(3):425–455
2. Camisón-Zornoza C, Lapiedra-Alcamí R et al (2004) A meta-analysis of innovation and organizational size. Organ Stud 25(3):331–361
3. Damanpour F (2010) An integration of research findings of effects of firm size and market competition on product and process innovations. Br J Manag 21(4):996–1010
4. De Jong JP (2011) Perceived competition and innovative intentions in dutch small and medium-sized enterprises. Int J Innov Manag 15(04):687–707
5. Gopalakrishnan S, Bierly P, Kessler EH (1999) A reexamination of product and process innovations using a knowledge-based view. J High Technol Manag Res 10(1):147–166
6. Madrid-Guijarro A, Garcia D, Van Auken H (2009) Barriers to innovation among spanish manufacturing smes. J Small Bus Manag 47(4):465–488
7. Mohnen P, Röller LH (2005) Complementarities in innovation policy. Eur Econ Rev 49(6):1431–1450
8. National Bureau for Industry & Commerce of the People's Republic of China SA (2015) The development report of the national market player in February 2015
9. National Bureau of Statistic of China (2015) 2014 statistical bulletin for national economic and social development of the People's Republic of China

Chapter 101
Evaluation of an E-catalogue Matching Mechanism in Public Procurement Notice Search

Ahmad Mehrbod, Aneesh Zutshi, António Grilo and Virgílio Cruz-Machado

Abstract Public procurement is the purchase of goods and services by a public authority. Open tendering opens up sufficient and fair competition between suppliers and ensures that public contracts are awarded fairly, transparently and without discrimination. A public e-procurement platform allows to reach these objectives through a public tendering e-marketplace. Tender notices can be used to search for business opportunities. Tendering websites provide keyword-based search and category-based notifications to the subscribers. The idea is that notification systems deliver tender opportunities to the suppliers and thus reduce the amount of time spent looking for these tenders. But according to potential wide range of products in a business sector, a supplier may receive an extensive list of notifications which makes it difficult to find the best matched opportunities with the supplier's product portfolio. Semantic-based technologies can be used to improve the search performance. In a previous work, a matching mechanism was developed to measure the similarity ratio of providers' product e-catalogues with a buyer's request. The matching mechanism uses domain ontologies to discover the semantic relationships among product data. In this paper, this product search approach is applied to a public tendering website, called Tenders Electronic Daily, in order to improve opportunity search service. The results show that the matching mechanism improves precision and recall measures.

Keywords E-procurement · E-catalogue · E-tender · Semantic search

A. Mehrbod (✉)
Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa,
Campus de Caparica, 2829-516 Caparica, Portugal
e-mail: a.mehrbod@campus.fct.unl.pt

A. Zutshi · A. Grilo · V. Cruz-Machado
Unidade de Investigação em Engenharia Mecanica e Industrial (UNIDEMI),
FCT/UNL, Campus de Caparica, 2829-516 Caparica, Portugal

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_101

101.1 Introduction

Public procurement, also called public tendering, is the purchase of goods, works or services by a public authority, such as a government agency. Open tendering opens up sufficient and fair competition between suppliers and ensures that public contracts are awarded fairly, transparently and without discrimination. This not only helps to achieve benefits such as increased efficiency and cost savings, but also can improve transparency in order to reduce corruption in procurement services.

While transparency is one of the important factors to the efficiency of a public procurement system, the usage of e-procurement is another important factor [11, 12]. E-procurement is the digitalization of important aspects of the purchasing process, such as search, selection, communication, bidding or awarding of contracts; with a specific emphasis on efficiency, transparency and policy in the public sector [13].

Public e-procurement platform allow to reach these objectives through a web-based open tendering e-marketplace. Since e-Tendering Marketplaces can be accessed anywhere globally, they can have great improvement on the accessibility and transparency of tenders and provide equal opportunities to all suppliers [3].

In public procurement e-marketplaces, suppliers search published tender notices in order to find available business opportunities that match their products. Many tendering websites provide simple keyword-based search. However the main drawback of exact keyword-based search mechanisms in product search is their problem in detecting semantically similar products [4]. Applying semantic technologies to product search mechanisms of e-tendering e-marketplaces can help suppliers to find similar and semantically related tenders to their product e-catalogues.

In procurement industry, companies usually exchange their product information in the form of product e-catalogues. E-catalogues are used by suppliers to describe goods or services offered for sale and may be used by buyers to source goods or services, or to obtain product or pricing details. This product information can be used by a product search mechanism in order to find and recommend similar product requests [5].

This paper uses an e-catalogue matching mechanism [8] to public tender search. Previously, the e-catalogue matching engine was developed in a B2B e-procurement platform in order to find business partners by measuring the similarity ratio of providers' e-catalogues with buyer's e-catalogues [10]. This paper applies and evaluates it in the tender search process using tenders published in a public tendering website, called Tenders Electronic Daily, in order to improve opportunity search service. TED is the online version of the 'Supplement to the Official Journal' of the EU, dedicated to European public procurements. According to the EU rules on public procurements, information of public procurement contracts and notices published in EU Member States, European Economic Area (EEA) can be accessed openly on TED.

This paper is organized as follows. Section 101.2 introduces the e-catalogue search engines that are mostly developed for product search in B2B e-commerce platforms. Section 101.3 reviews the e-catalogue matching mechanism used to search for tenders. Section 101.4 explains the application of the e-catalogue matching engine in the tender search and the evaluation mechanism used for measuring the search performance. Finally, Sect. 101.5 concludes the paper.

101.2 State of the Art

In existing tendering e-marketplaces, suppliers use keyword-based search engines to find products that match their conditions. Keyword-based search may have low precision especially when the users use synonyms for searching for a product. Furthermore theses search mechanisms cannot find potentially interesting products for the users that don't match their conditions exactly [4].

Semantic product search engines aim to encounter these problems by improving search capabilities using semantic web technologies in information retrieval process. An e-catalogue matching engine refers to a product search engine in the context of B2B e-commerce that matches a user search query with product e-catalogues. Search engines in the context of product matching is not only restricted to B2B e-catalogue matching engines. Many product search engines that search on various shopping websites or marketplaces encounter similar problems in order to provide comparative shopping search services [1, 2, 5].

101.2.1 Product Search Engines

A meta-search engine [7] was developed that matches different product categories from various e-commerce websites. The aim of the search engine is to find the most similar supplier product category to buyer's desired product category among underling categories and recommend the relevant supplier's e-commerce website to the buyer. Therefore the main task of the search engine is to match the categories, not the products. In order to use the search engine, the user has to describe his intent using a subclass-superclass relationship. Then a semantic extension of the query is made by expanding the class names using their synonyms from a dictionary called WordNet. The matching process is to calculate the relevancy measure between the extended query and the suppliers' product categories. Results will be a list of suppliers that their product categories have higher similarity with the category hierarchy that the user is looking for.

In a more comprehensive approach [6], the product search process is divided into two main parts including context search for finding the category of the desired product; and attribute related information search for finding the desired product. The developed category and attribute mapping methods regenerate a semantic query conforming to a specific shopping site's ontology with the original query written in a customer's ontology. But schema of the category and description of the attributes are pre-defined and fixed in the proposed model for product catalogues. The search engine makes the semantic translation of the user search query in SPARQL semantic query language and assumes that all underlying websites understand SPARQL standard queries.

In a similar approach [16], a general product search engine called XploreProducts aggregates product information from different sources using standardized semantic web technologies and vocabularies. Semantic matching in the proposed platform is based on two main steps including product identification and category mapping from different web shops. Product identification is to identify the product names that represent the same product. Since web-shops use different hierarchies and different names for describing product categories on the Web, the goal of category mapping is to map a category from the source taxonomy to a category from the target taxonomy. To cope with this problem the proposed solution uses an existing internal product category hierarchy and maps the new product categories to this internal taxonomy.

The category mapping algorithm in [16], computes a similarity score between the input category and each category in the target taxonomy and then chooses the target category that has the highest similarity. The algorithm assumes that the category taxonomy of the input category is available and maps this available taxonomy to its inner taxonomy.

101.2.2 VSM Search Engines

Some researches such as [8–10, 16, 17] have focused on adopting web search for matching products. These works are usually focused on product search in online shopping websites. But [8, 17] put forward this approach for matching B2B e-catalogues. Vector Space Model is an algebraic representation of documents as vectors in a high-dimensional space that is widely used by web search engines.

In [8] VSM has been used to measure the similarity ratio of providers' e-catalogues with a buyer's e-catalogue. Combinations of values and attributes of structured e-catalogues have been used to find the correlation of documents based on relationship of common items. In order to associate the structures in calculating similarity, levels of attributes in xml documents are included in the search element definition. This approach is extended [10] using a semantic mechanism which is not dependent on the underlying ontologies and schemas. The method uses a combinations of values, names and location of attributes of structured information to find the syntactic correlation of e-catalogues. It also uses domain ontologies to expand the matching mechanism with semantic relationships of data attributes.

In another approach, a product ontology is developed [15] for annotating html documents and an ontology-based adaptation of the Vector Space Model is proposed for e-commerce product information retrieval. This approach tries to unify the structure of all products in different websites that is the main shortcoming of such approaches which needs to develop data convertors or wrappers for each input. This approach works only for extraction and annotation scheme for specific known websites and any new website needs a new wrapper.

101.3 The E-catalogue Matching Engine

In a previous work an e-catalogue matching engine was developed and tested in a B2B e-procurement e-marketplace. This section provides a brief review on the features of the e-catalogue matching engine.

101.3.1 Data Indexing

In data indexing phase, search engines extract common terms or keywords from search data and produce a table of vectors. Each row or vector of this table represents a searchable element that can be for example a web page for web search engines or a product data specification in a product search engine. The advantage of this presentation is that simple vector operations can be used to determine the similarity ratio between search query and search elements.

One of the most important factors in index designing is the definition of the term that depends on the mission of the search engine. In a previous work [10] a method have been proposed to exploit the structures and semantics of product e-catalogues in term definition in order to calculate the similarity among products in B2B marketplaces. The e-catalogue matching engine that have been implemented using the method is capable to find similar products from various types of e-catalogues.

Usually B2B documents such as e-catalogues and tenders are structured in different levels. These levels show the value of different data segments in the document and can provide guidelines for search mechanisms. In order to use such guidelines to improve search performance, the implemented indexing process exploits not only the data attributes but also their position on the document structure. For more information about using the structures in term definition please see [8].

Furthermore, search engines utilize the semantic technologies to understand the meaning and relationship among data elements in order to cope with the shortages of keyword search [15]. The mentioned e-catalogue matching engine not only uses the structures, but also utilizes the semantic interpretation of the terms in data indexing process.

It uses the product classification systems and ontologies that are built based on them [14] to extract the semantic relationships among product data. Product classification systems are standard categorizations that are used for describing goods and services in e-procurement. These classifications can be used as semantic resources to describe the products mentioned in e-catalogues, tenders and other procurement documents as well.

101.3.2 Data Searching

In data searching phase, search engines use the same method as their indexing method to make a vector from search query. The search query vector will be compared to the data vectors that are made in the indexing phase in order to find the similar items to the search query from the data repository.

Usually in a preprocessing phase the user query is converted to a system understandable query. Depend on the mission of the search engine, a search query builder interface may be used by the search engine as an interface between user and the search engine. The e-catalogue matching engine provides a simple but efficient search query interface for product search. A search query can be inserted either directly in the form of text or by uploading e-catalogues to the search interface. Using product e-catalogues as search queries helps users to provide extra search query information to the search engine without using sophisticated search interfaces.

In e-procurement, suppliers provide the information of their products and services in the form of e-catalogues. Therefore a user who is interested to find a product or service, can simply find a list of relevant suppliers and products by uploading the e-catalogue of desired goods.

The search engine calculates the similarity ratio of the received query to all indexed products data. The output will be an ordered list of product e-catalogues that have the highest similarity scores. The similarity score for a product is computed based on the semantic and syntactic similarity ratio of the search query to the structure and specifications of the e-catalogues.

101.4 Evaluation on Tender Search

Since the mentioned e-catalogue matching engine achieved good results in finding similar products from e-catalogues, this paper survey the application of the engine for finding business opportunities in public tenders. In order to apply and evaluate the e-catalogue matching mechanism to a tender search application, the following test has been designed and implemented. As it can be seen in Fig. 101.1 the test evaluates the improvement of tender search performance using the e-catalogue semantic matching mechanics.

101.4.1 Data Gathering

The tender notices that have been published in the TED website are used as the tender repository in order to search for business opportunities. As mentioned Tenders Electronic Daily (TED) is the online version of the "Supplement to the Official Journal" of the EU that is dedicated to European public procurement. TED pro-

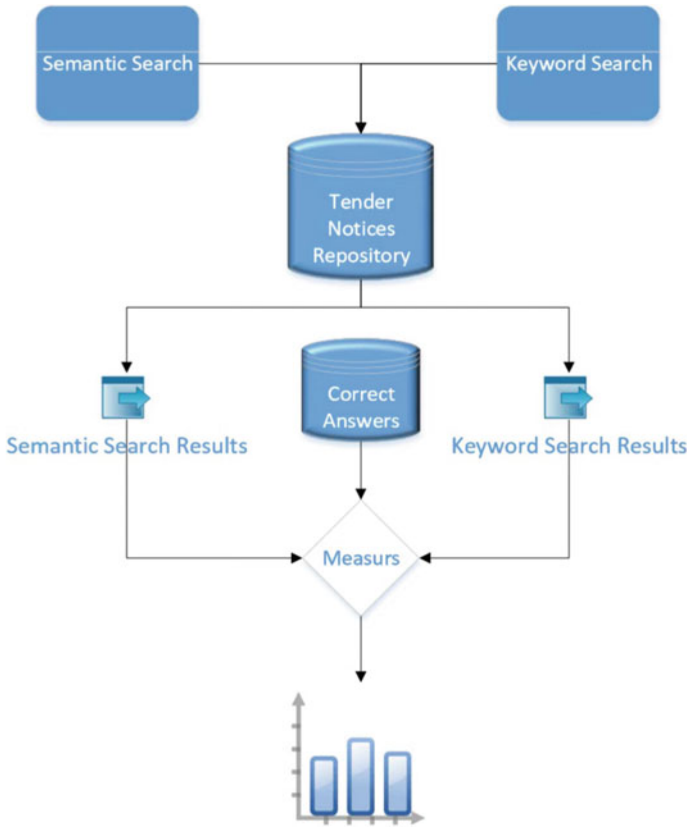


Fig. 101.1 Test Mechanism

vides free access to business opportunities from the European Union, the European Economic Area and beyond. Every day, from Tuesday to Saturday, a further 1,700 public procurement notices are published on TED. These procurement notices can be browsed, searched and sorted by country, region and business sector.

Since the website provides the category-based search, the tenders from each business sector can be retrieved separately. In order to make the test repository, tenders from three different sectors including “Cable, wire and related products”, “Insurance” and “Mobile telephones” are collected. All tenders from the three mentioned categories that have been published in 2015 in UK are collected and saved on the test repository. The test repository contains 28 tenders of “Mobile telephones” category, 107 tenders of “Cable, wire and related products” category and 550 tenders of “Insurance” category. Each category contains the tenders that are considered as the correct answers for the related search. Therefore a search mechanism will be considered as 100 % precise, if retrieves all the tenders from a category in response to a search query for the topic.

101.4.2 Measures

Precision and recall are two common metrics for measuring the performance of search engines. Recall is the ratio of the number of correct answers that are retrieved, to the number of all correct answers. Therefor the Recall factor shows the ability of a search engine to retrieve more correct answers from the search area. For example, since the collected repository contains 550 tenders in Insurance sector, if the search mechanism retrieves 400 of them in response to “insurance” search query, the recall measure will be 400/550.

Precision is the ratio of correct answers in all retrieved result set. Therefor the Precision factor shows the accuracy of a search engine to retrieve less false answers from the search area. For example, in the search repository there are 135 tenders from two other sections that are not related to Insurance and considered as false answers. If in the previous example the search engine returns 450 documents (400 correct and 50 wrong answers), precision is 400/450.

Generally the performance of a search engine is shown using Precision-Recall curves that represent these two inversely related metrics [10]. Finding a balance between these two metrics is dependent on the mission of the search engine.

101.4.3 TED Test Case

Two different search mechanism including keyword search and semantic search have been tested and compared on the data repository. The keyword search is considered as the basic approach of searching for opportunities in open tendering websites. The e-catalogue matching mechanism that is explained in the previous section is used as the semantic tender search. The results of these two mechanisms are compared with the correct answers that are gathered using category-based search service of the TED in order to calculate search performance measures. In simple words, the results of the semantic matching mechanism are compared with the results of simple keyword-search (as the basic search algorithm) for searching on the gathered tender repository.

Table 101.1 shows the precision and recall calculated for both mentioned search mechanisms. The results are reported for three different synonym search queries including ‘mobile’, ‘phone’ and ‘gsm telephones’ on the repository for finding tenders from “Mobile telephones” section. All available tenders in this section are considered as correct answers and the tenders from the other sections are considered as false answers. Since in practice we can calculate the precision in specific recall points, it is not easy to compare the results of different search mechanisms. In order to have comparable results, the precisions should report for standard recall levels. Thus the averages of all three queries are used to plot the interpolated standard precision-recall curve on Fig. 101.2. Each curve represents average interpolated precision-recall values for one search mechanism. In such curve the one to the top right shows

Table 101.1 Average interpolated precision-recall values

Recall	Keyword-based search				E-catalogue matching engine			
	Precision (phone)	Precision (gsm tele-phones)	Precision (mobile)	Average precision	Precision (phone)	Precision (gsm tele-phones)	Precision (mobile)	Average precision
0.1	100	100	100	100	75	60	75	70
0.2	0	0	100	33.33	71.42	35.71	83.33	63.48
0.3	–	–	87.5	29.16	77.77	35.71	70	61.16
0.4	–	–	90.9	30.3	55.55	38.46	76.92	56.97
0.5	–	–	92.3	30.76	27.9	27.9	75	43.6
0.6	–	–	87.5	29.16	22.58	22.58	77.77	40.97
0.7	–	–	89.47	29.82	16.83	16.83	68	33.88
0.8	–	–	0	0	0	16.37	18.44	17.4
0.9	–	–	–	0	–	12.35	17.79	15.07
1	–	–	–	0	–	0	0	0

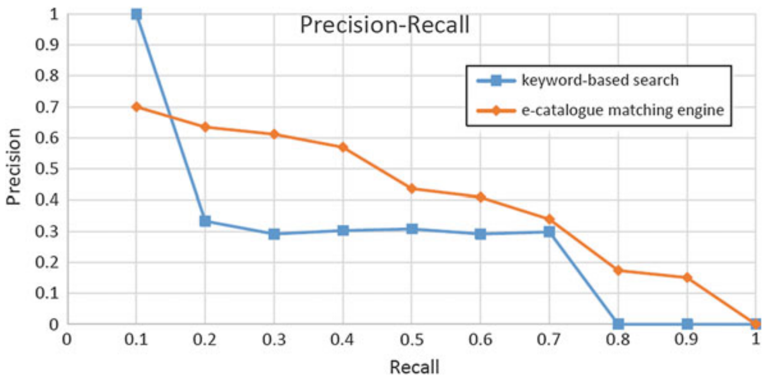


Fig. 101.2 Precision-recall

better search performance. As it can be seen on the figure, the semantic e-catalogue matching engine can improve tender search on a tendering website and consequently can help supplier in finding business opportunities. Even though the keyword-based search gets higher get higher precision when using exactly same keyword as exists in the data source, it has very low recall especially when searching using synonym keywords.

101.5 Conclusions and Future Work

Search service is one the technical factors in the success of a public procurement system. Usually public tender repositories provide simple keyword search services for finding business opportunities. Applying semantic technologies to the tender search process can improve search performance and help suppliers to find more relevant opportunities.

In this paper a semantic e-catalogue matching engine that had been developed in a B2B procurement platform, has been tested on the data gathered from TED public tender repository. The evaluation results shows the semantic e-catalogue matching engine can improve the search capabilities when searching using synonym terms in tender search. This helps the suppliers to achieve better results in finding relevant tenders that can facilitate finding business opportunities in public procurement marketplaces. In future work this method will be applied to more tenders from various public tendering marketplaces.

Acknowledgments The authors would like to acknowledge FCT/MCTES the financial support of UNIDEMI through the Strategic Project UID/EMS/00667/2013.

References

1. Ali MA, Shil NC et al (2010) Vendor selection using fuzzy integration. Int J Manag Sci Eng Manag 5(5):376–382
2. Ghimire S, Jardim-Goncalves R (2013) Framework for inter-operative e-procurement marketplace. In: Proceedings of the 2013 IEEE 17th international conference on computer supported cooperative work in design, pp 459–464
3. Grilo A, Ghimire S, Jardim-Goncalves R (2013a) Cloud-marketplace: new paradigm for e-marketplaces. Technol Manag IT-Driven Serv 13:555–561
4. Huang SL, Lin CY (2010) The search for potentially interesting products in an e-marketplace: an agent-to-agent argumentation approach. Expert Syst Appl 37(6):4468–4478
5. Julashokri M, Fathian M et al (2011) Improving recommender system's efficiency using time context and group preferences. Int J Adv Inf Sci Serv Sci 3(4):162–168
6. Kim W, Choi DW, Park S (2007) Agent based intelligent search framework for product information using ontology mapping. J Intell Inf Syst 30(3):227–247
7. Kwon IH, Kim CO et al (2008) Recommendation of e-commerce sites by matching category-based buyer query and product e-catalogs. Comput Ind Eng 59(4):380–394
8. Mehrbod A, Zutshi A, Grilo A (2014) A vector space model approach for searching and matching product e-catalogues. In: Proceedings of the eighth international conference on management science and engineering management, vol 281
9. Mehrbod A, Zutshi A, Grilo A (2014) Semantic and syntactic matching of e-catalogues using vector space model. In: Proceedings of the 11th international conference on e-business, pp 224–229
10. Mehrbod A, Zutshi A et al (2015) Matching heterogeneous e-catalogues in B2B marketplaces using vector space model. Int J Comput Integr Manuf 2
11. Miyamoto M (2015) Application of competitive forces in the business intelligence of Japanese SMEs. Int J Manag Sci Eng Manag 10(4):273–287
12. Molander P (2014) Public procurement in the European union: the case for national threshold values. J Public Procure 14(2):181–214

13. Roman AV (2013) Public policy and financial management through e-procurement: a practice oriented normative model for maximizing transformative impacts. J Public Procure 13(4):447–475
14. Stolz A, Rodriguez-Castro B et al (2014) PCS2OWL: a generic approach for deriving web ontologies from product classification systems. Semant Web: Trends Chall SE-43 8465:644–658
15. Turney P, Pantel P (2010) From frequency to meaning: vector space models of semantics. J Artif Intell Res 37:141–188
16. Vandic D, Dam JW, Frasincar F (2012) Faceted product search powered by the semantic web. Decis Support Syst 53(3):425–437
17. Zhang L (2009) A framework for an ontology-based e-commerce product information retrieval system. Technol Manag IT-Driven Serv 4(6):436–443

Chapter 102
A Bid Evaluation Method for Multi-attribute Online Reverse Auction

Ling Li, Xing Liu and Zhineng Hu

Abstract With rapid development of economy and society, online reverse auctions play an important role in procurement. In traditional reverse auctions. Buyers and sellers just compete on the price of the subject, regardless of other attributes like quality, performance, reliability and so on. However, this can not meet the real needs of the tender. Multi-attribute reverse auctions become more rational way. This paper study on the single item, multi-attribute reverse auction. Aiming at address the issues how to determine the total score of bidding program. This study focus on the bid evaluation method. Giving a more reasonable way to handle multiple expert scoring. This method can help to reduce the impact caused by the subjective preference. This paper use the Entropy-weight method to determine the weight of each attribute, and use normal distribution based method to integrate scores of each expert for attributes. Combining with these two method not only can improve auction efficiency, but also ensure fair in evaluation bidding process.

Keywords Bid evaluation · Multi-attribute bid · Reverse auction · Online procurement · Entropy-weight method

102.1 Introduction

With the advent of the Internet in our business world, e-commerce has changed the whole outlook of traditional auction ways. E-procurement is one of the procurement method based on the Internet. It is also an important part of e-commerce and have also been used by a number of large corporations in business-to-business transactions.

L. Li · Z. Hu (✉)
Uncertainty Decision-Making Laboratory, Sichuan University,
Chengdu 610065, People's Republic of China
e-mail: huzn@scu.edu.cn

X. Liu
Business School, Sichuan University, Chengdu 610065,
People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_102

Many of them have saved millions of dollars through online reverse auction usage in comparison to traditional procurement approaches [6]. The reverse auction different from the traditional auctions. It generally apply to a buyer and a number of potential sellers, such as the art auction. According to increasing demand of online reverse auction, how to choose the best one among many bid program become a key. The winner determination problem (WDP) is to find the winner of bids from the existing bids, and it is a computationally hard problem in multi-attribute reverse auction [3].

Among the existing literature, more and more attention is being paid to multi-attribute online reverse auction (MAORA). For multi-attribute single item procurement auction, Che [8] gave the auction model about two factors of the price and quality. His model select the highest one of the utility function as the best auction bidder. Branco [5] designed a two-stage auction mechanism assuming that suppliers' cost is relevant. Bepall and Richards [2] firstly introduced multi-attribute online reverse auction into economic field. Beil and Wein [1] designed an open ascending and multifactorial auction mechanism. Thiel [15] attempted to simplified multi-attribute into one-dimensional attribute to solve the MAORA problem.

In an industrial procurement scenario the buyer consider many important factors not only price, but also quality, construction period and so on. The procurement goods have multiple attributes. The Bid Evaluation become one of typical multi-attribute decision-making problem [13]. The bid evaluation expert score on the attributes of each bid. There are many classic model about multi-attribute decision-making problem, Some study discussed this problem as an algorithms for bid evaluation in multi-attribute reverse auction [4], he extended the research work and gave a winner determination model with configurable offers. Recently, several methods and techniques have been proposed for decision making in multi-attribute reverse auction with partial preference information. Butler et al. [7] presented useful preference elicitation models about AHP, conjoint analysis, and multi-attribute utility assessment.

In bid evaluation Scoring functions simply refer to the use of weights to aggregate multiple attributes to a single composite score. But in some cases, there are some inconsistencies in the judging matrices given by decision-makers due to the uncertain and complex nature of the problem, how to estimate the weights for price, quality, deliver terms. Some literature estimate such weights based on binary comparisons of bid vectors [12]. Some use one of the value function estimation techniques, such as the mid-value splitting technique [11].

The paper extended and improved on their works, and proposed a bid evaluation method combining the novel practical method for obtaining the weight vector of the OWA operator [16] and the Entropy-weight method for online multi-attribute reverse auction. The structure of this paper is as follows: in the next section, the model of winner determination problem in online multi-attribute reverse auction is developed, where the partial information on auctioneer's preference is presented as a set of linear inequalities. In Sect. 102.3, The method determining weight of each experts' scoring on one same attribute is described, and the method determining weight of each attribute is described. Finally, in the last section, conclusions are drawn.

102.2 Problem Environment

An online multi-attribute reverse auction experience a series of procedures. The whole process start with the analysis the properties of auctioned item. The group of execution determine several important attributes in the auction, and the group of experts must be organized. The multi-attribute online reverse auction process is shown in Fig. 102.1.

(1) Auction announcement

The online auction process of large enterprise groups and government agencies start with the publish of tender notice. A firm in an enterprise group proposes a procurement action. Giving the details of performance, quality, and other criteria on the supply items for purchase. Then, the online reverse auction center will draft the call tender for supply bids and publish it on the Internet using the Internet of the enterprise group. Meanwhile, it may inform qualified suppliers by phone or e-mail about the call tender.

(2) Bid submission

The next is bid submission. Interested suppliers can obtain the appropriate information and submit sealed bids via the Internet. The group of execution collect the tenders.

(3) Bid opening

Once the bidding closes, the e-procurement center will review all of the bids. Then, all the qualified bids will be announced via the Internet. Bids that are not

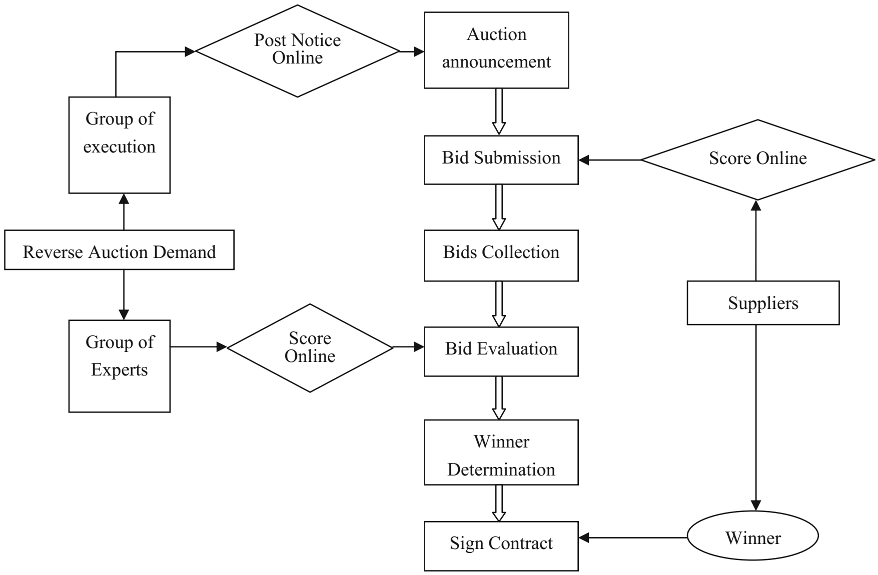


Fig. 102.1 The Multi-attribute online reverse auction process

competitive or appropriate will be eliminated. The details of the bids will not be changed to guarantee fairness and transparency in the auction.

(4) Bid evaluation

After the bidding has finished, the groups of experts will evaluate the bids. These technical and business experts will be separately selected from among experienced engineers and managers of the enterprise group. Scoring technical attributes. The technical experts will score the technical attributes of the bids received via the Internet. The expert technical referees will not be permitted to communicate with others who are not involved in the process. Scoring non-technical attributes. Simultaneously, the expert business referees will score the business attributes of the bids and also not be in contact with the technical experts.

(5) Winner determination

Once the two review groups have scored the results, the e-procurement center will calculate and rank all bids based on scores from the two referee groups. A winner will be determined, and the result will be announced to on the Internet.

(6) Ending online reverse auction

The winner and the buyer will sign a purchase contract. The above business process is almost paperless and is executed off-site. The low cost of online auction-based bids will attract more bids from different suppliers. Competition in online auctions usually is much fiercer than in traditional auctions. The fairness of the bid evaluation process is an important problem, and one we focus on in this article.

102.3 Model Formulation

In an industrial procurement scenario the buyer consider many important factors not only price, but also quality, construction period and so on. The goods for procurement have multiple attributes, the Bid Evaluation become one of typical multi-attribute decision-making problem. The bid evaluation expert score each of the attributes of each bid. Then, the total score of all bids can be calculated by the weighted sums of scores of all attributes by all referees. The bid with the highest total score will be the winner of the reverse auction. But it is difficult to giving comprehensive and consistent comparative judgments of all the bids. This section give the model of winner determination problem and giving the details of the method aggregate each experts score. Then the entropy-weight method is used to determine the weight of each attribute.

102.3.1 Solution Methodology

In the section, we consider in the multi-attribute reverse auctions. Before evaluation, Enough qualified experts should be selected in advance. They score on each attribute

Table 102.1 Variables description

Variable	Description
$U_{m\times n}$	The attribute judgment matrix
X_i	The attributes of each evaluated item ($i = 1, 2, \ldots, n$)
Y_j	Evaluation experts ($j = 1, 2, \ldots, m$)
a_{ij}	The score of i attribute given by expert j in the tenders
μ_n	The mean of the collection
σ_n	The standard deviation of the collection
W_i	The weight of the expert's score

for each bidding program. In the process of bid evaluation, the key point is to determine the weight and to obtain the total score of every expert on one attribute. In this paper, combining the normal distribution based method in OWA and entropy-weight method can get relatively objective evaluation results.

The variables used for bid evaluation in this paper is shown in Table 102.1.

Assume the auctioned project or supply item has m attributes and there are n experts score on the suppliers' project, where α_{ij} is the score of ith attribute given by expert jth in one of the tenders. For one of the candidate bid, the attribute judgment matrix $U_{m\times n}$ can be obtained by qualified experts as Eq. 102.1:

$$U_{m\times n} = \begin{array}{c} \\ Y_1 \\ Y_2 \\ \vdots \\ Y_m \end{array} \begin{array}{c} \begin{array}{cccc} X_1 & X_2 & \cdots & X_n \end{array} \\ \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{n2} & \cdots & a_{mn} \end{pmatrix} \end{array}. \tag{102.1}$$

102.3.2 Multi-experts Score Aggregation for Each Attribute

The key point of the problem related to ordered weighted aggregation (OWA) operator is to determine its associated weight. There is great number of method developed for obtaining the OWA weights. The normal distribution based method is firstly develop by Xu [16]. The main idea of the method is to assign very low weights to these "false" or "biased" opinions in a case. But this method has not been used to the fields of multi-attribute online reverse auction. This paper use the method to aggregate score of multi-experts.

In the progress of bid evaluation, each expert give own score on each attribute. How to deal with every expert's preferences becomes a different problem. In order to ensure fair and equitable, full consideration must be given to every expert opinion. This paper choose the method based on normal distribution for determining the weight of experts' scores. Because some individuals may assign unduly high or unduly low preference values to their preferred or repugnant objects. The method can reduce the influence of subjective preferences and get relatively objective scores.

From the attribute judgment matrix $U_{m\times n}$, where the $a_i = (a_1, a_2, \ldots, a_n)^T$ are the score vector of one of the attributes in a bid, and $w = (w_1, w_2, \ldots, w_n)^T$ is the weight vector of the n experts.

$$f(a_{ij}) = \frac{1}{\sqrt{2\pi\sigma_i}} e^{-\frac{(a_i-u_i)^2}{2\sigma_i^2}}, \quad i = 1, 2 \ldots m, \tag{102.2}$$

where μ_n and σ_n for score of ith attribute are obtained by the following formulas, respectively:

$$\mu_n = \frac{1}{n} \times \sum_{j=1}^{n} a_{ij}, \quad i = 1, 2 \ldots m, \tag{102.3}$$

$$\sigma_n = \sqrt{\frac{1}{n} \sum_{j=1}^{n} (a_{ij} - \mu_n)}, \tag{102.4}$$

where $f(a_i)$ can indicate the concentrate degree of experts preference. To relieve the influence of extreme preferences on the decision results, low weight is assigned to them. Considering that $w_i \in [0, 1]$, and $\sum_{i=1}^{n} w_i = 1$, we can obtain

$$w_i = \frac{\frac{1}{\sqrt{2\pi\sigma_i}} e^{-\frac{(a_{ij}-u_i)^2}{2\sigma_i}}}{\sum_{j=1}^{m} \frac{1}{\sqrt{2\pi\sigma_i}} e^{-\frac{(a_{ij}-u_i)^2}{2\sigma_i}}}. \tag{102.5}$$

Then by Eq. (102.2), we have

$$w_i = \frac{e^{-\frac{(a_{ij}-u_n)^2}{2\sigma_n^2}}}{\sum_{j=1}^{m} e^{-\frac{(a_{ij}-u_n)^2}{2\sigma_n^2}}}, \tag{102.6}$$

where w_i is the weight of the ith expert's score in the vector. By score weight of each expert, the total score of one attribute can be calculated.

102.3.3 Multi-attributes Aggregation for Each Tender

For a tender, In the condition of knowing the score of each attribute, determining the weight of each attribute weight is a different problem. The entropy-weight method is firstly developed by Shannon [14]. Now it has been widely used in engineering, technology, economic and other fields. It is one of the objective evaluation method. The basic idea of entropy weight method is to determine the objective weights according to the variability of index. Use information entropy to calculated the entropy weight of each index, then revise the weight of each index by the entropy. Finally, get the objective index weight.

We normalize the data of each indicator in the scoring matrix using the following equation. Assume there are k indicators $X_1, X_2 \ldots, X_n$, where $X_i = (a_{1i}, a_{2i}, \ldots, a_{mi})$. The value of the index data after normalization is β_{ij},

$$\beta_{ij} = \frac{\alpha_{ij} - \min \alpha_i}{\max \alpha_i - \min \alpha_i}. \tag{102.7}$$

Then calculate the proportion p_{ij} of the jth evaluation values under the ith factor

$$p_{ij} = \frac{y_{ij}}{\sum_{j=1}^{m} y_{ij}}. \tag{102.8}$$

Then calculate the entropy of each attribute, according to the definition of entropy in information theory, the entropy of each attribute is E_{ij},

$$E_{ij} = -\frac{\sum_{i=1}^{m} p_{ij} \ln p_{ij}}{\ln n}. \tag{102.9}$$

The smaller entropy is, the greater the degree of variation of indicators and the greater the weight is. So we can re-corrected index weights in accordance to the entropy. As knowing the entropy for each indicator, the weight of each attribute can be determined

$$U_i = \frac{1 - E_j}{\sum_{i=1}^{m} (1 - E_j)}, \tag{102.10}$$

where U_i is the target weight.

102.3.4 Multi-attribute Online Reverse Auction Bid Evaluation Progress

Step 1. Determine the weights of each supplier's score. As the score of the experts concentrate around a certain level, scores which are too high or too low are rare. The method based on normal distribution can relieve the influence of unfair arguments on the decision results by weighting these arguments with small values. We can determine the weight of each expert by Eq. (102.6).

Step 2. Calculate total point on each attribute. We get the weight of each expert's score w_i, then we can get the total point of each attribute by the following equation;

$$Q_i = \alpha_{ij} \times w_{ij}, \qquad j = 1, 2, \ldots, n, \tag{102.11}$$

where Q_i is the expert total point on ith attribute.

Step 3. Calculate the entropy of each attribute. In order to calculate the weight of each attribute. We use the entropy-weight method. Firstly the scoring matrix should be standardized by Eq. (102.7). Then according to the definition of entropy in information theory, the entropy of each attribute can calculated by Eq. (102.9).

Step 4. Determine the weight of each attribute. Knowing the entropy of each attribute, we can obtain weights of each attribute by Eq. (102.10).

Step 5. Calculate the total score of the candidate tender. For one bid, we obtain the total score of each attribute and the weight of each attribute. We can calculate the total score of the bid

$$W = \sum_{i=1}^{n} (U_i Q_i), \tag{102.12}$$

where W is the final score of this tender program, we can get the final score of each tender program and find the highest one as the optimal tender.

102.3.5 Case Study

In order to test the method. Consider a winner determination problem of an online multi-attribute reverse auction. An university need to purchase Lab Security Systems. It decided to via the way of reverse auction. Taking demand into account and apart from the price, Lab Security Systems must meet various requirements, like equipment performance, energy consumption, defeat rate, after-sales maintenance and so on. The university organized groups of experts for scoring bid product.

In this example, we consider five attributes, price, equipment performance, energy consumption, defeat rate and after-sales maintenance. Five experts scored five attributes of the bidding scheme given in Tables 102.2, 102.3, 102.4 and 102.5.

Table 102.2 Experts score graph of each attributes for supplier 1

Experts	Price	Equipment performance	Energy consumption	Defeat rate	After-sales maintenance
1	8.9	7.1	8.7	8.5	8.5
2	8.3	7.6	9.0	8.4	7.9
3	7.8	8.1	8.2	7.6	7.8
4	7.8	8.6	8.5	8.1	8.3
5	7.7	8.9	9.0	8.8	8.7

Table 102.3 Experts score graph of each attributes for supplier 2

Experts	Price	Equipment performance	Energy consumption	Defeat rate	After-sales maintenance
1	9.1	7.1	7.7	8.5	8.1
2	8.1	8.6	8.6	7.4	8.3
3	7.6	8.9	8.2	8.6	6.9
4	8.8	7.6	8.5	7.1	7.9
5	8.5	8.9	7.5	8.3	7.5

Table 102.4 Experts score graph of each attributes supplier 3

Experts	Price	Equipment performance	Energy consumption	Defeat rate	After-sales maintenance
1	8.0	7.6	7.7	7.5	8.1
2	7.4	7.3	6.9	7.4	8.9
3	7.8	8.9	7.2	8.1	7.3
4	8.8	8.6	9.1	8.3	8.6
5	6.7	8.9	7.3	7.8	7.7

Table 102.5 Experts score graph of each attributes

Biddings	Price	Equipment performance	Energy consumption	Defeat rate	After-sales maintenance
Suppliers 1	8.1084	8.0493	8.6795	8.2772	8.2399
Suppliers 2	8.4139	8.1642	8.2615	7.7900	7.7304
Suppliers 3	7.7421	8.2313	7.8240	8.0182	8.1185

There are five experts e_j $(j = 1, 2, 3, 4, 5)$. These experts provide their individual preferences for the price of Suppliers 1 (in Table 102.2). Experts not only consider the level of prices but also consider the cost-effective then give the comprehensive scoring to the attribute of price. Form Table 102.2 the given preference values are as follows:

$$a_{11} = 8.9, a_{21} = 8.3, a_{31} = 7.8, a_{41} = 7.8, a_{51} = 7.7.$$

By Eqs. (102.3) and (102.4), the mean of the score collection is $\mu_1 = 8.1$. The standard deviation of the score collection is $\sigma_1 = 0.4516$.

Then from Eq. (102.2), it follows that

$$f_{11} = 0.6334,\ \ f_{21} = 0.5958,\ \ f_{31} = 0.5988,\ \ f_{41} = 0.5988,\ \ f_{51} = 0.6032.$$

The weight of each expert's score by Eq. (102.6) as follows

$$w_1 = 0.2091, w_2 = 0.1966, w_3 = 0.1976, w_4 = 0.1976, w_5 = 0.1991.$$

The total score of price is $Q_1 = 8.1084$ by Eq. (102.11)

As this example. We can get total score of each attribute in Table 102.5. Scores of three supplier's item attribute is as follows.

Then we calculate the weight of each attribute with the Entropy-weight method, we can get standardized matrix by Eq. (102.7) (Table 102.6).

By Eq. (102.9), we have the entropy of each attribute of three suppliers in Table 102.7.

According to the entropy of each attributes, we can Determine the weight of each attribute by Eq. (102.9).

Combine with the Table 102.7, the final score for each tender is shown in the following Table 102.5,

As the supplier 1 get the highest score. We can choose it as the bidding winner (Tables 102.8 and 102.9).

Table 102.6 Standardized score graph of each attributes three suppliers

Experts	Price	Equipment performance	Energy consumption	Defeat rate	After-sales maintenance
Suppliers 1	0.5453	0	1	1	1
Suppliers 2	1	0.6313	0.5114	0	0
Suppliers 3	0	1	0	0.4684	0.7617

Table 102.7 Entropy graph of each attributes

	Price	Equipment performance	Energy consumption	Defeat rate	After-sales maintenance
Entropy	0.2055	0.1804	0.2131	0.2207	0.1288

Table 102.8 Weight graph of each attributes

	Price	Equipment performance	Energy consumption	Defeat rate	After-sales maintenance
Weight	0.1961	0.2023	0.1942	0.1923	0.2150

Table 102.9 Score graph of three suppliers

	Suppliers 1	Suppliers 2	Suppliers 3
Score	8.2673	8.0660	7.9902

102.4 Conclusion

The bid evaluation is a hard problem in multi-attribute reverse auction. Based on the expert scoring, how to deal with experts' scores is difficult to be objective and reasonable. The study develops a bid evaluation method for multi-attribute online reverse auction. This method combine the novel practical method for obtaining the weight vector of the OWA operator and the entropy-weight method. The use of normal distribution based method can relieve the influence of extreme preference on the decision results by weighting them low values. This method take the views of each expert into account and give an objective score. The application of entropy-weight method can make full use of the information provided by the original data.

This paper integrate and improve two methods in the field of multi-attribute online reverse auction. It can help to make a objective and scientific synthesis decision. But it only involves one part of the process in multi-attribute online reverse auction. In the future we will study on other parts of the multi-attribute online reverse auction.

Acknowledgments This research was supported by the projects XQ14B04 and SKZX2015-SB87.

References

1. Beil DR, Wein LM (2003) An inverse-optimization-based auction mechanism to support a multi-attribute RFQ process. Manag Sci 49(11):1529–1545
2. Bepal M, Richards DJ (2001) Reach for the stars: a strategic bidding game. Economica 68(272):489–504
3. Bichler M, Kalagnanam J (2005) Configurable offers and winner determination in multi-attribute auctions. Eur J Oper Res 160(2):380–394
4. Bichler M, Kaukal M, Segev A (1999) Multi-attribute auctions for electronic procurement. In: Proceedings of the first IBM IAC workshop on Internet based negotiation technologies, pp 18–19
5. Branco F (1997) The design of multidimensional auctions. RAND J Econ 28(1):63–81
6. Brunelli M (2000) E-auctions save millions for QuakerOats and Smith Kliene Beecham. Purchasing 128(1):8–22
7. Butler JC, Dyer J, Tomak K (2008) Enabling e-transaction with multi-attribute preference model. Eur J Opera Res 186(2):748–765
8. Che YK (1993) Design competition through multidimensional auctions. RAND J Econ 24(4):668–680
9. Cramton PC (1997) The FCC spectrum auctions: an early assessment. J Econ Manag Strategy 6(3):431–495
10. Jun Y (2010) Multicriteria fuzzy decision-making method using entropy weights-based correlation coefficients of interval-valued intuitionistic fuzzy sets. Appl Math Model 34:3864–3870
11. Keeney RL, Raiffa H (1976) Decisions with multiple objectives: preferences and value trade-offs. Wiley, NewYork
12. Korhonen P, Silvennoinen K, Wallenius J, Öörni A (2012) Can a linear value function explain choices: an experimental study. Eur J Oper Res 219(2):360–367

13. Sandholm TW (2000) Approaches to winner determination in combinatorial auctions. Decis Support Syst 28(1–2):165
14. Shannon CE, Weaver W (1947) The mathematical theory of communication. The University of Illinois Press, Master's thesis, Urbana
15. Thiel SE (1988) Multiondimensional auctions. Econ Lett 28(1):37–40
16. Xu Z (2005) An overview of methods for determining OWA weights. Int J Intell Syst 20(8):843–865

Chapter 103
Dynamic Strategy Based Optimization Method for Inventory Problem: Case Study in Guizhou Power Grid

Ning Liu and Fengjuan Wang

Abstract In this paper, we put forward a dynamic strategy based optimization method for power supply bureau of Guizhou Power Grid to solve the order and inventory problem of 10 kV bench transformer. Guizhou Power Grid Corp intends to standardize the distribution of 10 kV bench transformer, materials for construction will be sent to the warehouse of the local power supply bureau, and then distributed to the construction site. In order to ensure the construction schedule and reduce the material purchasing and storage costs, local power supply bureau needs to consider the balance of ordering and inventory. In this paper, local power supply bureau's order and inventory is considered as a finite stage deterministic inventory problem. We established a finite stage deterministic model, then the dynamic strategy is applied to work the model out, lastly, a real word case of Guizhou Power Grid is applied to the model, and the model calculated the ordering policy with the lowest total cost of order and inventory.

Keywords Dynamic strategy · Inventory problem · Guizhou power grid · 10 kV bench transformer

103.1 Introduction

Material management of enterprises in energy industry such as electric power industry, there are problems such as large amount of equipment requirement, fast technology renewal, intensive variety and complex regulation [5]. Some materials, due to the design requirements, program validation, raw materials procurement, production

N. Liu
Logistics Services Center, Guizhou Power Grid Co., Ltd, Guiyang 550002,
People's Republic of China

F. Wang (✉)
Business School of Sichuan University, Chengdu 610064,
People's Republic of China
e-mail: 821700381@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_103

cycle, inspection and testing, in transit and other internal and external reasons, usually a relatively complete procurement cycle up to several or even several months [6, 8]. At the same time, the particularity of the power industry has brought about a series of complex management problems, such as large fluctuations in production demand, poor planning, changing the situation of the site and the special technical requirements [4, 7, 9]. And a 10 kV bench transformer, even after optimization design, still has more than 80 kinds of materials needed. Because of the differences of the type, capacity, reactive power compensation, inlet and outlet ways, etc. A regional power supply bureau has hundreds of categories and specifications of materials, showing the extreme complexity of materials supply. Which requires materials management department to be timely, accurate and efficient to supply materials, and shortens the procurement and delivery period of various types of materials to meet the production needs while reducing costs.

In order to improve the efficiency of the supply chain, in August 2013, Southern Power Grid Corp launched a 10 kV bench transformer's "four standardized" (standard design, standard materials, standard distribution, standard construction) pilot work. Guizhou Power Grid Corp. is required to improve the standardization of logistics management, information, intelligence and intensive level in accordance with the requirements of the "four standardized". The local power supply bureaus is thinking about how to make the lowest cost ordering under the existing warehouse capacity and material needs of the premise. Calculating the procurement quantities by quantitative order (or a regular order) when production is determined by demand and the discrete is uniform, inventory often deviate from the actual needs [1], sometimes resulting in a backlog [2], sometimes resulting in shortages [3], which leads to poor economic efficiency [9]. In order to solve this problem, to order according to the actual needs of the situation and in accordance with the actual needs of each time period is necessary. However, this order may not be the most economical way, because the inventory, although reduced, but frequent orders will increase the cost of ordering. The dynamic programming method can be used to solve this kind of problem if the overall optimization is used to plan the reasonable order times and the order quantity at each time.

This paper is organized as follows: this paper uses the dynamic programming method. First, define the variables that affect decisions, and then the parameters describe the dynamic planning needs be defined. In the above premise, put forward the demand uncertainty stock limited stage dynamic programming solution. This method is then applied to Zunyi, Guizhou Power Grid Company branch ordering process, to find the optimal ordering policy for its planning period; Finally, we draw conclusions and propose future research directions (Fig. 103.1).

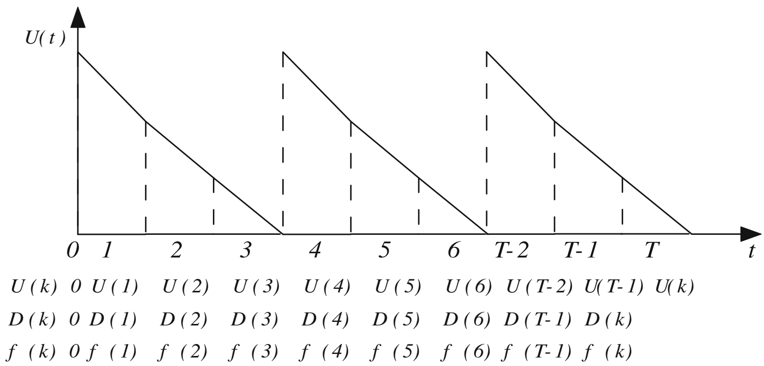


Fig. 103.1 The change of inventory when the demand is not stable

103.2 Methodology

103.2.1 Definition

The characteristics of finite deterministic inventory model is the demand of materials can be divided into several periods, in the same period the demand is constant, but in different period, demand is changing, namely the inventory problem is to be resolved in the following scenarios: the demands are known but non smooth and inventory problem runs in limited stage.

Inventory problems typically include the following elements:

(1) Demand: The purpose of inventory is to meet the needs of the terminal. The demand can be a constant, or a random variable.
(2) Supplement: To fill demand and reduce the storage by the complement of the goods, replenishment can be obtained through the external order and internal production in two ways.
(3) Shortages Treatment: As the demand for or supply lag time may be random, and therefore the material shortages is likely to occur. If it failed to fully meet the demands, Two methods may be performed. First, when the goods arrive, make up for the lack of goods; and second, the lack of goods are no longer replenished.
(4) Count method: In order to understand the inventory, it is necessary for stocks to be checked. There are two general inspection methods, continuous inventory or cyclical inventory.
(5) Cost: The cost of inventory systems typically include ordering fees, storage fees, Shortages fees and other related costs.

To describe the dynamic programming problem, four basic parameters are required: decision variables, state transition variables, the number of decision-making stage, the system benefit function.

Decision-making and stages: Decision is a choice or action made to deal with the problems, in dealing with a real problem, you may have several decisions or multiple decision points, to this end, the entire issues can be divided in to several interrelated stages. Here recorded as stage $k(k = 1, 2, \ldots, n)$.

States and state variables: Each stage of the multi-stage decision-making process has its own characteristic, the starting point of each stage is named as the state of the phase, and the state variables is used to describe the characteristics of each states. Here recorded as U_k.

Decision variables: In each stage there is a decision, variables used to describe the decisions are called decision variables. Generally we use X_k to represent the decision variables of phase k.

Strategy and sub strategies: In a multi-stage decision making process, if each decision variable $X_k(U_k)$ has been identified, then the whole process is completely determined. Saying the decision variable sequence $\{X_k(U_k), X_{k+1}(U_{k+1}), \ldots, X_{k+n}(U_{k+n})\}$ is a sub strategy starting from k. Strategies which meet the the target best are called the the optimal strategy and the sub-strategy closest to the predetermined target is called optimal sub-strategy departure from X_k.

103.2.2 Model Formulation

(1) Notations

In order to facilitate the problem description, the following notations are introduced.

k:	The period of inventory, $(k = 1, 2, \ldots, n)$;
c:	The price of commodity, (yuan per piece);
H:	The price of commodity storage, (yuan per piece);
W:	The cost of ordering, (yuan a time);
$X(k)$:	The quantity of commodities ordered at stage k, (/ piece);
$D(k)$:	The quantity of commodities needed at stage k, (/ piece);
$f(k)$:	The minimum total cost at the end of stage k, (/ yuan);
U_k:	The quantity of commodities in warehouse at the end the stage k, (/ piece);
$c_k(X)$:	The cost of ordering of stage k, (/ yuan);
$c_2(k)$:	The cost of inventory of stage k, (/ yuan);

(2) Assumptions

To model the dynamic strategy based optimization method for inventory problem in this paper, assumptions are as follows:

Variety of goods:	The variety of goods is unitary.
Inventory method:	Take inventory at the end of each cycle.
Initial inventory:	The initial inventory is 0.
Operational phase:	The inventory system runs in K limited time period.
Demand for commodities:	Demand $D(k)(k = 1, 2, \ldots)$ is already known.

Instantaneous availability:	Commodities are complemented at the beginning of each cycle.
Cost component:	Expenses including ordering fees and inventory fees.
Situation in short supply:	Short of supply is not allowed.

(3) Dynamic programming model

Supplementary volume at the beginning time of stage k:

$$X(k) \geq 0, (k = 1, 2, \ldots, K). \tag{103.1}$$

Ordering costs of stage k :

$$c_k(X) = \begin{cases} W + cX, & X > 0. \\ 0, & X = 0. \end{cases} \tag{103.2}$$

Inventories at the end the stage k is defined as U_k, and the inventory cost of stage k is defined as:

$$c_2(k) = HU_k, (k = 1, 2, \ldots, K). \tag{103.3}$$

The order sequence, which has the minimum total cost in the limited period is an optimal solution. Obviously, this inventory model, inventories meet the following conditions:

$$U(k) = \begin{cases} U(k-1) + X(k) - D(k), & k = 1, 2, \ldots, K. \\ 0, & k = 0. \end{cases} \tag{103.4}$$

Due to the assumption that the shortage phenomenon does not occur, and the need for goods are supplemented instantaneous, so for any of the optimal solution $\{X(k)\}$, $(k = 1, 2, \ldots, K)$, only if the inventory levels dropped to 0, would we consider ordering:

$$U(k-1)X(k) = 0, (k = 1, 2, \ldots, K). \tag{103.5}$$

For the optimal solution $\{X(k)\}$, assuming that the last ordering occurs at the starting time of stage $t(1 \leq t \leq K)$, that is $X_t > 0$ and $U(t-1) = 0$, from Eq. 103.6 we can know that:

$$X(t) = \sum_{k=t}^{K} D(t). \tag{103.6}$$

Record the minimum sum cost of all the k phases as $f(k)(k = 1, 2, \ldots)$:

$$\begin{cases} f(K) = \min\{W + cX(t) + \sum_{k=t}^{K} HU(k) + f(t-1)\}, & 1 \leq t \leq K. \\ f(0) = 0, & k = 0. \end{cases} \tag{103.7}$$

103.2.3 Case Study

For the purpose of demonstrating the effectiveness of the proposed optimization method, in this section, a real world case problem in Guizhou Power Grid is shown.

(1) Presentation of Case Problem

The pilot work, dedicated to create a standard design, packaging, distribution and installation process for 10 kV transformer Bench, is a new challenge in the process of material distribution of Power Grid Corp. Under the premise of the four standardization, the material procurement process is as follows: At the beginning of the year, the local power supply bureau submitted the annual plan to the provincial company according to the type and quantity of the transformer. Then, a summary of the total provincial demand to the Council bench transformer is made by logistics department. The company's bidding departments then find suppliers in the way of open tender. After an agreement with the supplier, the local land bureau can pick from the supplier in accordance with the annual plan.

Now we consider this issue from the perspective of the local power supply bureau. In this problem, the material needs for the planning period (one year) of the local power supply bureau is known, planning period can be divided into 12 stages and at the end of each stage they need to consider whether to purchase materials of the next stage or not. When it comes to the cost, ordering fees and storage fees are taken into account. In order to ensure that the project is completed on time and reduce the cost of materials storage, which stage should the local power supply bureau require the supplier delivery, here we will take the 110 pilot products as an example to study the order strategy.

(2) Data collection

The data is collected in the Guizhou Power Grid Corp, documents includes: Package summary table of 10 kV bench transformer; Standard sub table of 10 kV bench transformer; Purchasing management business guide of 10 kV bench transformer; Contract management business guide of 10 kV bench transformer.

(3) Result of Case Problem

In 2014, Guizhou Power Grid Corporation selected 110 projects as the pilots of standard distribution. The material costs as well as the pilot number of each bench transformer is shown in Table 103.1.

Table 103.1 The material costs and the pilot number of each kind of bench transformer

Types	A	B	C1	C2	D1	D2	E1	E2
Material costs	43900	127211	132258	129973	136013	136152	136018	130018
Polit number	5	82	2	3	10	3	1	4

Considering the number of different types of bench transformer in the pilot projects, this paper discusses the material distribution and warehouse storage of type B transformer. The price of this transformer is 127211 yuan.

After taking the framework tender, the material distribution is done by the suppliers, but this part of the expenses will occupy a certain proportion of the total cost, and therefore, these costs are still paid by the local power supply bureau. Distribution costs is shown in Table 103.2, $W = 2267.5$ yuan.

Warehousing staffing is shown in Table 103.3.

The change of the storage cost is mainly labor costs, we estimate the warehouse management fee as 200 yuan per piece a month. $H = 200$ yuan.

Ordering cost $W = 2667.5$ yuan, inventory management cost $H = 200$ yuan per month a piece, order cycle $L = 1$ month, price of bench transformer is 127211 yuan each, virgin inventory is zero, now consider how the order to make the lowest cost. Then the establishment of a dynamic programming model. Order stage k is from January to December ($k = 1, 2, \ldots, 12$), the decision variables X_k represents the quantity of the kth month ordered, State variables U_k represents the inventories when the kth cycle ended, $D(k)$ represents the product demand of stage k, then the

Table 103.2 The distribution costs

Number	Items	Price	Quantities	Total costs
1	Cardboard box	15	10	150
2	Cable ties	50	0.5	25
3	Tape	15	0.5	7.5
4	Wooden box	100	2	200
5	Packing tape	100	0.5	50
6	Packaging belt clip	40	0.5	20
7	Nails	10	0.5	5
8	Bags	2	20	40
9	Labor costs	190	3	570
10	Shipping fees	1600	1	1600
11	Total	2667.5		

Table 103.3 The stuff needed in the warehouse

Types	Num.	Requirements	Duties
Logistics personnel	2	Familiar with the distribution business	Responsible for goods delivery and documents transfer
Warehouse personnel	1	Familiar with bench transformer material layout	Responsible for the materials stacking and sorting in the warehouse

Table 103.4 Dynamic programming model analysis results

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Demands	3	4	5	5	4	5	8	8	10	10	5	5	82
Order	12	0	0	14	0	0	16	0	20	0	20	0	82
Inventories	9	4	0	9	5	0	8	0	10	0	10	0	55

state equation is $U(k) = U(k-1) + X(k) - D(k), k = 1, 2, \ldots, K$. At the end of stage k, the inventory is U_k, the storage costs $H_k(U_k) =$ The optimal function $f(k)$ indicates the minimum cost from the first stage of the initial inventory level of 0 to the end of the stage k. The sum of the minimum cost at the end of the K phase is:

$$\begin{cases} f(K) = \min\{W + cX(t) + \sum_{k=t}^{K} HU(t) + f(t-1)\}, \; 1 \le t \le K. \\ f(k) = 0, \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad k = 0. \end{cases} \tag{103.8}$$

By using the method of pushing forward, the results obtained are as follows:

From Table 103.4, the optimal decision-making system is

$$\begin{gathered} x_1^* = 12, x_2^* = 0, x_3^* = 0, \quad x_4^* = 14, \quad x_5^* = 0, \quad x_6^* = 0, \\ x_7^* = 16, x_8^* = 0, x_9^* = 20, x_{10}^* = 0, x_{11}^* = 20, x_{12}^* = 0. \end{gathered}$$

Namely, order 5 times, the maximum inventories is 55, the total cost of the optimal decision is:

$$f\,(K) = \min_{1 \le x \le 12} \left\{ 2667.5 + 13000X\,(t) + \sum_{k=t}^{12} HU\,(k) + f\,(t-1) \right\} = 3347500.$$

103.3 Conclusions

Combined with model demonstration, the inventory problem of local power supply bureau is considered as a deterministic inventory problem in a finite period. Using dynamic programming method to complete the modeling analysis, a reasonable order sequence can be developed, namely, the optimal purchasing plan. The optimal procurement plan can make the total procurement cost and inventory cost and the minimum cost under the premise of the construction schedule, is the most economic order sequence.

The dynamic programming method is successful in solving multi-stage problems. It is mainly in the condition of satisfying the demand of different periods, making reasonable decisions in order to reduce the cost of ordering and the rise in storage costs. Although the above algorithm can find the optimal procurement program, but when the number of stages grow, the calculation of the problem is very large, so it was suggested heuristic approximation algorithms to reduce the amount of calculation. In addition to the production management and economic management, the dynamic programming method has been widely used in the fields of engineering technology, military and other fields.

References

1. Babai MZ, Syntetos AA et al (2009) Dynamic re-order point inventory control with lead-time uncertainty: analysis and empirical investigation. Int J Prod Res 47(9):2461–2483
2. Berman O, Kim E (2004) Dynamic inventory strategies for profit maximization in a service facility with stochastic service, demand and lead time. Math Methods Oper Res 60(3):497–521
3. Bernstein F, Federgruen A (2004) Dynamic inventory and pricing models for competing retailers. Nav Res Logist (NRL) 51(2):258–274
4. Fisher AS, Kaplan SJ (2000) Method for supplying automatic status updates using electronic mail. US Patent 6,047,264
5. Happonen A (2012) Adjusting inventories based on demand prediction using dynamic inventory balancing model. In: 2012 Proceedings of PICMET'12: technology management for emerging technologies (PICMET). IEEE, New York, pp 3549–3565
6. Hariga MA (1994) Economic analysis of dynamic inventory models with non-stationary costs and demand. Int J Prod Econ 36(3):255–266
7. He Q, Luo W (2012) Research on the dynamic inventory control of vulnerable articles. In: 2012 fifth international conference on intelligent computation technology and automation. IEEE, New York, pp 291–294
8. Song JS, Zhao Y (2009) The value of component commonality in a dynamic inventory system with lead times. Manuf Serv Oper Manag 11(3):493–508
9. Yang B, Gao C et al (2015) Dynamic inventory and pricing policy in a periodic-review inventory system with finite ordering capacity and price adjustment cost. Math Probl Eng 2015:1–8

Chapter 104
Modeling of Stochastic Vertical Stationary Transportation Systems

Asaf Hajiyev, Turan Mammadov, Mirvari Hasratova and Narmina Abdullayeva

Abstract We consider mathematical models of stochastic vertical transportation (lift) systems with arbitrary values of customer intensity. Such systems have complicated structure and their investigations by analytical approaches face with some troubles. Our aim is to introduce the various control strategies for these systems, compare them and find the advantage of some policies. By modeling a behavior of such systems on a computer and getting numerical results for different efficiency indexes and characteristics we can compare the various control policies and to derive the optimal among them.

Keywords Supplier selection · Uncertain variable · Uncertain programming · Genetic algorithm

104.1 Introduction

In the second part of the XX century the methods and approaches of queuing theory have been applied in investigating of traffic flows, elevators and escalators systems, airports, control of traffic flows in tunnels, shipping, transportation, communication systems, network of computers and others [9, 12, 14, 15]. All of these systems are unified in one common idea—queues with moving servers. Investigation of such types of queues leads to a construction and research of new mathematical models and in the frames of such mathematical models the new methods of investigations are formed. Simulation, modeling, intensive methods of computational statistics and other modern IT methods for queuing systems are a wide field of investigations, but even now there are a lot of unsolved problems, for instance with simulation of rare events, observation of traffic jams, different car accidents and other, which are happened with a small probability. Perhaps, even modeling will not allow the

A. Hajiyev (✉) · T. Mammadov · M. Hasratova · N. Abdullayeva
PABSEC (Parliamentary Assembly of Black Sea Economic Cooperation),
Academician of Azerbaijan National Academy of Sciences, Baku, Azerbaijan
e-mail: asaf.hajiyev@gmail.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_104

observation of rare events, because sometimes for their observing it is necessary to have long period of modeling and it is difficult to estimate how much time is needed for modeling of rare events.

One of the main tools for investigation of complicated queuing systems is empirical and simulation data and their analysis. By simulation we can get numerical results of the different characteristics of systems. But for taking decisions that are rich in content, it is necessary to have statistical analysis of simulation data [3, 11, 16].

Complex usage of analytical and computer methods allow taking a rich in content decisions for queues with complicated structures and making corresponding recommendations for practical applications.

Typical examples of queues with moving servers are elevator systems [2, 4, 7]. In 1953 there was an opening ceremony of the new building of M.V. Lomonosov Moscow State University, where there were three big elevator halls, with six elevators in each. In one of the elevator hall some elevators went up to $1, 2, \ldots, n/2$ floors (n is a number of the floors) and others went up to $1, (n/2) + 1, (n/2) + 2, \ldots, n$ floors. (see Fig. 104.1), elevator hall in Moscow State University)

The great Kolmogorov, who participated in the opening ceremony immediately pointed out, that it is the wrong control policy and instead of the $1, (n/2) + 1, (n/2) + 2, \ldots, n$, floors he suggested to use $1, 2, \ldots, 2n/3$. But with the use of the modeling of the behavior of elevator systems on the computer, was shown that the Kolmogorov's advice was correct [4]. The alternative to such control can be a system where one elevator serves even numbered floors and the other one serves odd numbered floor. However, the modeling on the computer showed that in this system the average waiting time of a passenger is greater than the average waiting time of a passenger in the system where one elevator serves $1, 2n/3, (2n/3) + 1, \ldots, n$.

One other interesting unofficial control policy was used in the students' dormitory of Lomonosov Moscow State University, which was called "higher-lower". There were 18 floors in the student dormitory and four elevators operated between the 1st to 12th, 14th, 16th and 18th floors (for the elevators to work more rapidly they skipped the odd numbered floors, after 12th), there was another elevator hall for service between the 1st and 10th floors. If an elevator came to the first floor and the first student yelled the word "HIGHER" then the elevator would be used for going up only to the higher floors (16th and 18th) and next elevator will give service to the 12th, 14th and other floors. If the first call would have been "LOWER", then the elevator would operate between the lower floors (12th, 14th and other floors). (see, Fig. 104.3, student dormitory in MSU).

The mathematical models and modeling this strategy on a computer, which confirmed an advantage of the "higher-lower" strategy were constructed and investigated [4, 7].

The construction and investigation of mathematical models of queues with delays as a control function gave unexpected results. Introduction of delays, "HIGHER-LOWER" and others control policies in queues, allowed the diminishment of expectation of waiting time of customers before service in some models.

There is another control policy by elevators system "EVEN-ODD", when one elevator gives service only for "EVEN" and other for "ODD" floors. Comparing of "HIGHER-LOWER" with "EVEN-ODD" showed an advantage of "HIGHER-LOWER" control policy.

Construction of mathematical models of such systems leads needs using of some deep mathematical conception and facts from theory of point processes [1, 8]. Some control problems by these systems were investigated in [5, 6, 10, 13].

In the paper various control policies for elevator systems are investigated. By simulation it was derived an advantage of one system in comparison with other. Numerical examples of simulation and graphs, describing a behavior of various parameters are given.

104.2 General Mathematical Model

Let us consider the system $L_k F_n C_{xx}$, which means k lifts, which serves customers in the building with n floors and within control policy xx (Fig. 104.1). The flow of customers, which arrives for service, is stationary and $\lambda_{i,j} < \infty$, $(\lambda_{ii} = 0; i, j = 1, 2, \ldots, N)$ is the intensity of customers who goes from ith floor to the jth.

104.2.1 Collecting Systems

If lift goes from ith floor to up, then lift must check existence of customers at the jth, floor $(j > i)$, which are going up and takes (collect) them. Similarly, if lift goes from ith floor to down, then lift must check existence of customers (going down) at the jth floor $(j > i)$ and takes (collect) them. Such systems with bounded volume have some deficiency, because in saturated regime (high intensity of customer flow at the each floor) some customers, who arrived into the system earlier, will get service later, than customers who arrived into the system later. For instance, in the pick hours sometimes customers from upper floors are waiting longer than customers at the first floor. Such situation can be observed in skyscrapers at the office buildings during lunch time and in the evening.

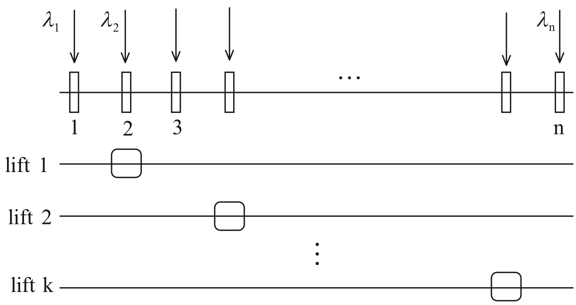


Fig. 104.1 Introduce so called "collecting systems"

104.2.2 Direct Service Systems (Non-collecting Systems)

If lift goes from ith floor to jth ($i < j$), i.e. lift goes from down to up, then in spite of that there are customers (going up) between ith and jth floors (but who arrived into the system later than customer from ith floor) lift directly goes to ith floor, i.e. lift ignores customers who arrived into the system later than customer at the ith floor. It is a like to FIFO system, because the principle first income first outcome is realized here. If there is a customer at the ith floor (going down) and lift goes from jth floor $j > i$ (from up to down) then lift ignores all customers between jth and ith floors (who arrived later than customer at the ith floor) until the instant while customers from ith floor get service. Such lift systems can be observed in some not so high living buildings.

104.2.3 Mixed Systems

If lift goes from up to down it collects customers at the below floor. But moving from down to up lift ignores customers while customer in lift gets service.

Second and third systems are widely used today in the not so high living buildings, but in skyscrapers are usually used “collecting systems” with sufficiently large volume, i.e. first system.

In modern living buildings there exist various complicated control policies for such systems. For instance, if there are two lifts and both are going to down then collection of customers will be distributed between lifts. The lift system gives commands to lifts, which floors should be served and which floors should be ignored. Arrival of any a new customer into the system leads to the correction of control policy, i.e. to the new commands. Such systems also will be considered below.

104.2.4 Remark

For comparing of the different control policies in the capacity of efficiency index we will use a customer average waiting time before service. Below will be given a formula for calculation of this an efficiency index. There exists other efficiency indexes (for instance, energy expenses, service time, lift single transport race and others) but we will use a customer average waiting time before service. Usage more than one efficiency indexes lead to more complicated problems but it will be a subject of our future investigations.

104.3 Simulation

For simulation of lift systems the following notations are introduced.

i: a current number of customer, which arrived into the system and get service;
j: a number of the floor, where ith customer arrived;
k: a number of the floor, where a customer leaves lift;
t_i: an instant, when ith customer arrived into the system;
i: an order number of the lift, which gives service for ith customer;
t_i^{sf}: a starting service instant for ith customer (an instant, when ith customer will get a lift);
t_i^{ss}: an instant, when ith customer finishes service (leaves lift).

For an each customer we will introduce 7-dimensional vector $i, j, k, t_i, l, t_i^{sf}, t_i^{ss}$, which will be saved in the archive and allows to compute desired efficiency indexes. During a simulation the archive of the 7-dimensional vectors will be created and using the components of that 7-dimensional vector the various efficiency indexes of the systems can be calculated, for instance waiting time before service, service time (time interval while a customer was in the lift), energy expenses and others. For instance, a customer average waiting time before service can be calculated as

$$\sum_{i=1}^{N} (t_i^{sf} - t_i^{ss})/N,$$

where N is a number of all served customers, i.e. number of all the 7-dimensional vectors. An average service time can be calculated as and so on.

$$\sum_{i=1}^{N} (t_i^{ss} - t_i)/N.$$

For simulation the following values of technical characteristics were used.

$$h\,[k] = (k-1)h_{1,} \;\; h_1 = 3 \;\text{ s}.$$

$h_2 = 2\,\text{s}$ is stopping time interval at the floor (opening and closing a door) $m = 5$ (the volume of lift, maximum number of people in the lift). We will consider several cases: System $L_2F_{21}C_{IL}$, where IL (independent lifts) means non-controlled policy, i.e. lifts operating independently.

System $L_2F_{21}C_{DL}$, where DL (dependent lifts) means controlled policy, i.e. the nearest lift serves a customer.

The system $L_2F_{21}C_{DP}$, where DP means distributed policy, i.e. floors are distributed between lifts. There are different ways of distribution: OE (odd-even) is first lift serves odd numbered floors, the second lift serves even numbered floors; UL (upper-lower) is first lift serves floors $1 - 2N/3$, the second lift serves floors $2N/3 - N$;

DP (distributed policy) is that if both lifts are going down then the floors, where are customers calls, will be distributed between lifts: first lift will serve some floors and second others. Arrival of a new customer into the system will change distribution policy. Such systems are used in skyscrapers.

104.4 Experimental Results

For low values of intensity ($0 \leq \lambda \leq 0.17$) a customer average waiting time before service $W = W(\lambda)$.

In the figures below axis x-meas intensity of a customer input flow and axis y means a value of efficiency index (a customer average waiting time before service). In the figures will be used different colors for a customer average waiting time before service for different control policies. Simulation results show that for small values of an intensity a customer waiting time before service for *IL*-system is less than the same characteristic for *DL*-system, i.e. *IL*-system is preferable. Explanation of this phenomena is the following: for small intensity of an input flow at a customer preceding time in the *IL*-system positions of the lifts are the following: one lift is located at the first floor and another at the floor $i = 2, 3, \ldots, n$; For *DL*-system at a customer preceding time both lifts are located at the first floor, which means that in fact only one lift operates. Hence, operation of two lifts more preferable than operation of one. For high intensity of input flow a close lift will go to a customer call and hence a customer waiting time in *DL*-system less than in *IL*-systems. (see Fig. 104.2). Comparison of these two systems show, that for small intensity *DL*-system is preferable than *OE*-system (small difference between a customer average waiting time before service), because for small intensity *OE*-system operates like a system with one lift. For some interval of intensity a difference between efficiency index becomes larger but for high intensity operating of these two systems are the same and difference between efficiency index becomes smaller and smaller (see, Fig. 104.3). Comparison of simulation results of these two systems show that both

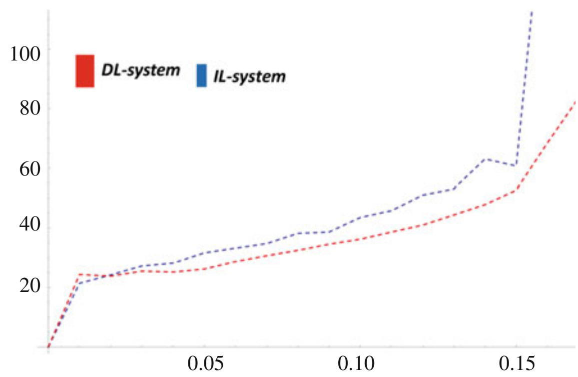


Fig. 104.2 Comparison of the *DL* and *IL* systems

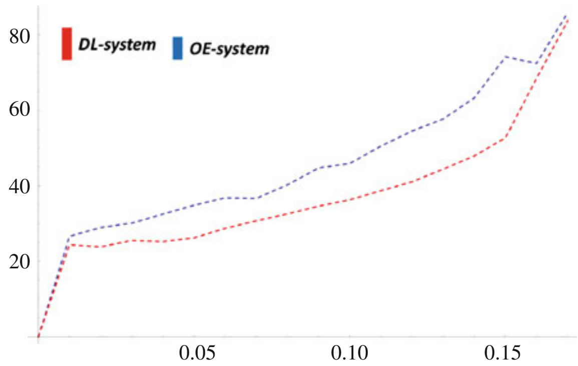


Fig. 104.3 Comparison of *DL* and *OE* systems

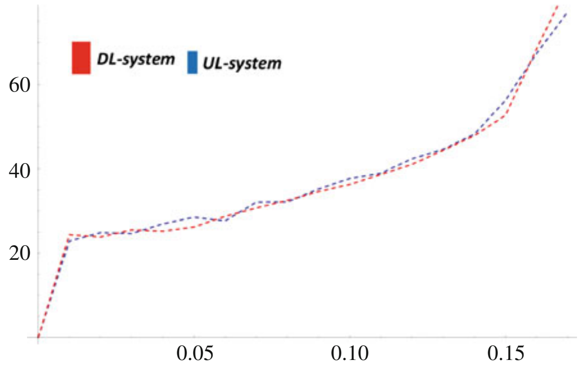


Fig. 104.4 Comparison of *DL* and *UL*-systems

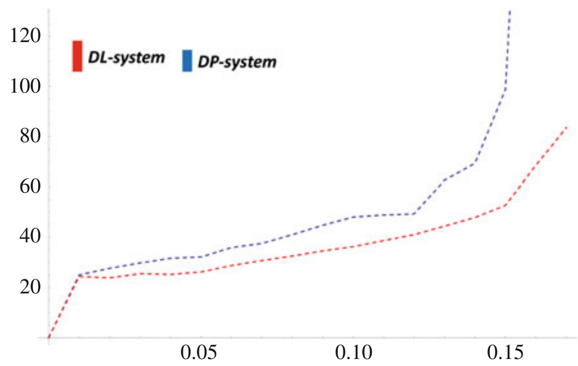


Fig. 104.5 Comparison of *DL* and *DP*-systems

systems are operating effectively and it is difficult to make any advantage (see, Fig. 104.4). Comparison of these two systems shows advantage of *DP*-system in a customer average waiting time before service. It is clear that *UL*-system is trying to re-distribute customers between lifts and hence a customer average waiting time before service is the best among of above mentioned systems (Fig. 104.5).

104.5 Conclusion

All above mentioned system can be compared by simulation. Results of simulation show that an optimal policy has *DP*-system, because a customer average waiting time before service takes minimum value. We do not state that *DP*-system is the best or optimal. Perhaps there are exist a lot of various systems with better service but among of above mentioned *DP*-system is optimal.

For exact comparison it is necessary to make statistical data analysis but it is a subject of our next investigations.

Acknowledgments This paper was supported by the Science Development Foundation under auspice of the President of the Republic of Azerbaijan—Grant No. EİF-2012-2(6)-39/13/1.

References

1. Belyaev Y (1963) Limit theorems for thinning flows. Theory Probab 8(2):175–184
2. Belyaev Y, Hajiyev A, Dugina T (1978) Control by system of vertical transports. Stat method control theory 12:194–195
3. Belyaev Y, Hajiyev A et al (1974) Simulation of operating two elevators. Soviet State Fund Algorithm Program 1(2):52–59
4. Belyaev Y, Hajiyev A et al (1977) Comparative analysis of simple vertical transport. Stat method control theory (3):97–103
5. Deb RK (1978) Optimal dispatching of a finite capacity shuttle. Manag Sci 24(13):1362–1372
6. Deb RK, Serfozo RF (1973) Optimal control of batch service queues. Adv Appl Probab 5:340–361
7. Dobrushin R (1956) On poisson low for particles distribution in space. Ukr Math J 8(2):127–134
8. Gadziev A (1980) Minimization of the mean waiting time in the systems with recurrent service. Vestnik Moskovskogo Universiteta Seriya 1 Matematika Mekhanika (3):19–23
9. Geyzis Eday L (1968) Mathematical models of transportation flows. IEEE 4:94–109
10. Hajiyev A (1985) Delays reducing the waiting time in queueing systems with cyclic services. Scand J Stat 301–307
11. Ignall E, Kolesar P (1974) Optimal dispatching of an infinite-capacity shuttle: control at a single terminal. Oper Res 22(5):1008–1024
12. Kerner BS (2009) Introduction to modern traffic flow theory and control: the long road to three-phase traffic theory. Springer Science & Business Media, Heidelberg
13. Lee HS, Srinivasan MM (1990) The shuttle dispatch problem with compound poisson arrivals: controls at two terminals. Queueing Syst 6(1):207–221
14. Muñoz J, Daganzo C (2002) Traffic and transportation theory. Editor Map Taylor
15. Newell GF (1974) Control of pairing of vehicles on a public transportation route, two vehicles, one control point. Transp Sci 8(3):248–264
16. Osuna E, Newell G (1972) Control strategies for an idealized public transportation system. Transp Sci 6(1):52–72

Part VII
Industrial Engineering

Chapter 105
Green and Lean Model for Business Sustainability

Susana Duarte and V. Cruz-Machado

Abstract Understanding how efficiently we use the role of resources in the organization namely natural resources in use, water, materials and energy consumption is a vital step for designing business strategies to tackle inefficiencies. Green and lean model for business sustainability will be presented and indicators for a resource efficient and green business will be discussed. Organizations must understand how resources are use and how can be used, making better decision about the use of those environmental, social, and economic resources. However the resources are not only a business concern. All organizations in a specific region should be evaluated for the knowledge of the progress on the road to sustainability. This study aims to be a preliminary study of how to use green and lean management concept as a step towards to sustainability. To the authors this is the first attempt to understand and develop a model through green and lean concepts to improve critical sustainability issues, enhancing the efficiency of the resources.

Keywords Lean philosophy · Green management · Natural resources · Diagnosis model

105.1 Introduction

Business sustainability or sustainable business is the top of the issues that organizations nowadays must take into consideration. Business sustainability is considered the integration of the 3P (i.e. people, profit and planet) into the different organizational levels: sustainable operations, tactics choices and strategy formulation. Also business sustainability is the plan of action that organizations have in terms of environment, social and economic issues. Broek [33] stated that currently, sustainability

S. Duarte (✉) · V. Cruz-Machado
Faculdade de Ciências e Tecnologia (FCT), UNIDEMI, Departamento de Engenharia Mecânica e Industrial, Universidade Nova de Lisboa, 2829-516 Caparica, Portugal
e-mail: scd@fct.unl.pt

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_105

becomes part of the core business. It is a serious challenge to achieve excellence, perfection, and sustainability in the modern dynamic and global world [32]. The increasing of environment and social trends are connected with critical factors such as pollution control, resource scarcity, energy consumption, among others [9, 33]. The environmental issues or green issues are connected to green management. Green management is about the reduction of negative impacts or risks on the business operations [9, 20]. Different organizations can deploy different business practices but in the end can achieve high levels of performance in terms of sustainability indicators. Further, green management have a strong relation with lean management [3, 5, 14]. The application of the two concepts simultaneous is a strong formula for the development of business sustainability [3, 14]. However there is still little understanding how they should be integrated to achieve excellence performance in terms of sustainability [3]. The consumption continues to growth, day by day; therefore it is important to understand how resources are use and how can be used. In addition there are few studies on models synchronizing both green and lean management approaches at the same time and the role of inter-organizations collaboration undertaking to achieve environmental, social and economic targets [9, 11, 12]. Organizations must understand the impact of business on critical sustainability issues and how business can be optimized through green and lean management principles, practices and techniques.

In addition this subject is a country concern and how organizations can produce more with less, without sacrifice customer values and needs. Of course there are regulations and norms in all different countries to help and make the organizations to be more sustainable. However, it is not always accounted the consumption of environmental, social, and economic resources needed, at the country level or a specific region. Thus the motivation for this study is to present an idea for countries to develop their level of sustainability assessment parameters, to benchmark their data with others countries.

The remainder of this paper is organized as follows: in Sect. 105.2, a theoretical background on green and lean management system and business sustainability are presented; in Sect. 105.3, a conceptual green and lean model for business sustainability are developed; in Sect. 105.4 a value chain system diagnosis is proposed; finally, some concluding remarks will be drawn.

105.2 Theoretical Background

105.2.1 The Green and Lean Management System

The green and lean management system is not a new definition among researchers [13, 14, 19, 24]. Green and lean are in harmonization within business management that helps organizations to achieve an effective and efficient value chain. But achieve an excellent and perfect business is something that is still utopian. Many correlations can be made between both approaches, in different business functions

[17, 25]. The idea is to use different principles, practices, techniques or tools where both approaches complement each other to achieve the best combination towards sustainability.

Examples of green and lean models were presented in the research of [12] where they present a lean and green framework considered criteria as: (1) people, (2) leadership; (3) stakeholders; (4) strategic planning; (5) processes and (6) results. These criteria are interconnected and through continuous improvements it is possible achieve better results in way the organizations reach a best-in-class structure. Also Bergmiller and McCright [4] presented a comprehensive lean and green systems model where highlight the value of the management system, the applications of a number of waste reduction techniques and the reaching of the targeted business results. Important elements are: (1) employee involvement; (2) leadership; (3) planning; (4) information and analysis; (5) process management; (6) focus on interested parties; (7) metrics and goals and (8) focus on results [4].

Dues et al. [14] mentioned that lean and green overlap is focus on: (1) people and organization; (2) lead time reduction; (3) supply chain relationship and (4) waste reduction techniques. Waste reduction is the root of a green and lean approach. The lean wastes are considered as [30, 34]: overproduction, waiting, transportation, inappropriate processing, unnecessary inventory, unnecessary motion, and defects; the green wastes are excessive resource usage, excessive power usage, excessive water usage, greenhouse effects, rubbish, pollution, and eutrophication [34]. Green waste is concerned as “an unnecessary or excess use of resources or a substance released to the air, water, or land that could harm human health or the environment” [30].

Therefore for a green and lean implementation is important to put in action the right practices with the right principles giving more attention to their business and the value given to customer. With green and lean approach is possible to control and reduce the utilization of the role of resources in the organization. The green and lean approach can be seen as a new manner of doing business.

105.2.2 Business Sustainability

According to Evans and Kelly [16] “the need for sustainability is resonating across the world; however there are variations in how it is being addressed”. On the 21st century, business sustainability has become a trend for organizational business. Economical and fair use of resources has been one of the trendiest approaches [22]. For Labuschagne et al. [22] and Pojasek [26], business sustainability is “the adoption of business activities and strategies which must meet the needs of the organizations and its stakeholders today while also protecting, sustaining, and enhancing the environmental, social and economic resources that will be needed in the future”. To achieve sustainability most organizations select as their guiding principles the eco-efficiency and socio-efficiency [15].

Organizations are looking for a safe approach to implement and help the growth of the business [8]. Pojasek [26] presented a universal business where considered that every business activity is:

(1) managed by leaders;
(2) performed by people;
(3) planned strategically and planned tactically;
(4) is influenced by a sort of stakeholders;
(5) is improved with information and knowledgement;
(6) controlled and executed by process and
(7) constrained by limited resource [26].

Another idea mention by Broek [33] is that there is no only one approach to achieve sustainability; however there is an action plan where considered a number of procedures namely:

(1) engage employees;
(2) investigate where it is possible conserve resources;
(3) investigate where can get a strategic sourcing (supplier engagement);
(4) optimize network and provide integrated service;
(5) implement conservation measures throughout operations;
(6) improve efficiency of site operations and balance the economies;
(7) seek ways to integrate a strategy with sustainability in all organization areas;
(8) communicate green efforts to stakeholders;
(9) support industry and community sustainability initiatives.

Gao and Bansal [18] suggested that the integration of environmental and social issues with core strategic issues in the organizational decision-making process is needed to really reproduce the principles of business sustainability. In their research, Ahi and Searcy [1] used key characteristics of business sustainability namely environmental, social, economic, resilience, stakeholder, long-term focuses and volunteer. According to UN Global Compact and Business for Social Responsibility [29], business organizations depend on a range of issues as the industry sector, supply chain footprint, stakeholder expectations, business strategy and organizational culture. Others characteristics are mentions such as: (1) transparency; (2) management; (3) governance; (4) protect reputation and brand value and (5) minimize business disruption from environmental, social and economic impacts [29]. Different approaches for business sustainability with different key characteristics, best practices or procedures are comment. An aspect that is sure: for their existence, organizations have to guarantee profit.

105.3 Green and Lean Model for Business Sustainability

Our societies are increasingly inundated by problems of scarcity and discrimination, climate change, and human population growth, so it is imperative the conservation of the resources [10]. This requires a model that helps in changing the paradigm

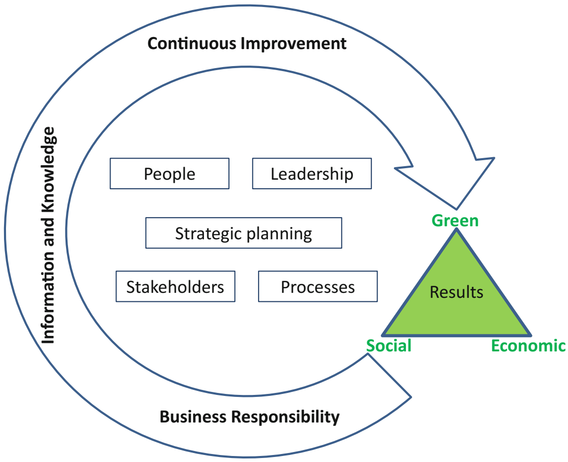


Fig. 105.1 Green and lean model for business sustainability

of sustainability. Environmental, social and economic issues find their places in lean concept and obviously in green concept [8]. The green business implies the incorporation of eco-friendly concepts into the value chain system [7]. In a lean business if one partner in the chain prospers, the others will also benefit, creating a virtuous cycle [23]. The green approach develops situations that merge environmental protection and financial success [27]. In addition lean business can be used as a powerful approach to improve sustainability [28].

A green and lean framework can be developed for de maturity of business sustainability. In Fig. 105.1 is presented a green and lean conceptual model. This model for business sustainability have a set of criteria namely leadership, people, strategic planning, stakeholders and processes which represent business activities through a green and lean principles, practices and techniques. In addition the concept of this model is that green and lean interrelations will result in outcomes that will be obtained by the criterion results. The results represent what organization is achieving in terms of environmental, social and economic issues. Therefore through the results, which they are obtained by indicators, it is possible that organizations plan, implement, and continually improve the business sustainability. Based on what Pojasek [26] indicates in their research; this model considered elements of action namely: (1) continuous improvement (where a culture of improvement, innovation and learning is needed); (2) information and knowledgement (where is used the data and knowledge to improve the results), and (3) business responsibility (where organization must behave in a responsibility manner) [26].

These elements allied with green and lean principles, practices and techniques in different organizational functions will be improved the overall business sustainability. The key purpose is to apply the use of the resources in an efficiency manner, through a green and lean approach.

It is said indicators reveal opportunities [31, 32]. And through continuous improvement, and information and knowledge of business it is possible to organizations understand how resources are use and how can be used, making better decision about the use of those environmental, social, and economic resources. "Organizations must understand the impact of business on critical sustainability issues" [32]. Therefore a set of indicators for measuring the progress on the road to sustainability can be a kind of solution for organization consumption in terms of resources [8]. The ability to measure and understand what each indicator represents is important, in order to manage in line with the results. This will allow choosing which necessary green and lean activities must be implemented or improved. Table 105.1 presents a number of indicator that measure the progress to business sustainability.

It is possible to define indicators and evaluate the progress of business through environmental, economic and social resources. However a possible problem is to build a comprehensive system of indicators for monitoring and control of the progress towards sustainability to achieve an evaluation in terms of a region [31]. In fact "Breakdowns by country/region" is considered as part of the organizational profile which may register sales/revenues, costs or employees [21].

105.4 The Green Value Chain System Diagnosis

Although there are various international efforts on measuring sustainability, only few of them have an integral approach taking into account environmental, social and economic aspects [27]. "However, the ability to balance production and consumption and also improve society with economic development is hard to measure resulting in little agreement on natural capital approaches to drive sustainability" [28]. In other perspective, Dakovl and Novkov [8] mentioned that the business attitude differs from country to country but basically the nature of business is to look for profit.

The United Nations Environment Programme considered that consumption continue to growth [32]. One example given by the author is the volume of water that a country needs to extract to keep economy going. To them, this issue is measure by the water use to generate each monetary unit of Gross domestic product (GDP). The doubt relative to how to measure this volume of water and how to improve it, in a continuous way, is become visible. This can be developed through the application of green and lean model presented (Fig. 105.1) where the deployment of green and lean principle, practices and techniques are developed to achieve better resource efficiency. However this was considered for an organization and not for a group of organizations, a region or a country. It is imperative to develop a value chain system diagnosis.

In the literature it appears the idea given by Supply Chain Operations Reference (SCOR) model. This model is used to evaluate and improve supply chain performance, i.e. evaluate competitive performance of the entire chain, allowing organizations to compare and link their operations using a common language and measurement base. Actually this model integrates the application of green best practices and measures [6]. The goal is that all entities on supply chain can measure their performance with the same indicators. In addition, Anand and Kodali [2] presented

Table 105.1 Indicators for business sustainability

Economic	Ref.	Social	Ref.	Environment	Ref.
-Value added to waste costs	[8]	-Share of suppliers monitored on their social performance	[8]	-Resource consumption per unit of production, sales or employee	[8]
-Change in retained earnings at end of period		-Gender profile		-Intensity of resource use	
-Labor productivity		-Share of hours of training relative to the total hours worked		-Resource consumption reduction	
-Debt to production ratio		-Change in the number of employees receiving job skills training		-Ratio of renewable raw materials used to total material flow	
-Human capital investment as percentage of profit		-Share of employees surveyed who agree that their workplace is safe and comfortable		-Distance travelled per unit of production, sales or employee	
		-Share of pre-tax earnings donated to the community		-Waste per unit of production, sales or employee	
				-Emissions per unit of production	
				-Emissions reduction	
				-Waste reduction	
-Value added to resource costs	[8, 31]	-Illness & disease reduction	[8, 31]	-Greenhouse gas emission	[8, 31]
-Contribution to GDP		-Safety improvement			
-Employment contribution		-Workforce diversity			
-Resource efficiency	[15]	-Average hours of training per year per employee	[8, 21]	-Energy consumption	[31]
				-Water consumption	
				-Material consumption	
				-Greenhouse gas emission	
				-Material Import and export	

(continued)

Table 105.1 (continued)

Economic	Ref.	Social	Ref.	Environment	Ref.
-Direct economic value generated and distributed, including revenues, operating costs, employee compensation, donations and other community investments, retained earnings, and payments to capital providers and governments	[21]	-Monetary value of significant fines and total number of non-monetary sanctions for noncompliance with laws and regulations	[21]	-Initiatives to provide energy efficient	[21]
-Financial implications and other risks and opportunities for the organizations activities due to climate change		-Monetary value of significant fines for noncompliance with laws and regulations concerning the provision and use of products and services		-Energy saved due to the conservation and efficiency improvements	
				-Percentage of materials used that are recycled input materials	
				-Total environmental protection expenditures and investments by type	

a lean supply chain framework where implementing the necessary elements of lean approach across the supply chain. The purpose is to improved performance of the entire supply chain [2].

With this information and based on green and lean model, Fig. 105.2 was designed. The objective is all organizations in the same region, measure their business sustainability with the same indicators. The outcomes represent a global measure by country and by region. Therefore it is possible understand better the trends of resource use and resource efficiency in the region and how to implement green and lean approach for improvement. Indicators of business sustainable should be selected by the appropriate communities of interest [27]. Due the continuous improvement this indicators could change through time. Also the road to sustainability can be different to every organization but the final destination should be the same for all.

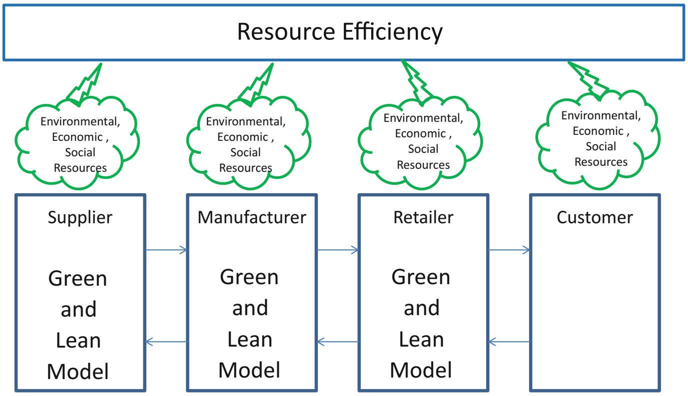


Fig. 105.2 Green value chain system diagnosis

With this System diagnosis it is possible benchmark against organizations, countries or considered regions in terms of sustainability. This will allow countries or regions understand where the opportunities for improvement are (i.e. how much resources the country are using and how it can use the resources in a more efficiently manner).

105.5 Conclusions

Green and lean integrated approach is used to manage the business in almost kind of industry to work in an efficient and efficacy way, through the reduction of every kind of wastes. A concern by the population is the conservation of resources, specially the natural resources as water, energy or material.

The purpose of this research was to develop a comprehensive model that through the green and lean implementation was possible to improve critical sustainability issues, enhancing the efficiency of the resources. To analyze the improvement of the organization, a system with indicators for monitoring and control of the progress towards sustainability is also proposed.

Future research is needed. Understand which green and lean practices are more relevant to apply to achieve better results in terms of resources consumption. In addition as the evaluation proposed is on every entity of the value chain and in all value chains on a specific region, is crucial that a report should be developed in terms of specific indicators giving data of the evolution of the business sustainability in a specific region.

Acknowledgments Authors would like to acknowledge to UNIDEMI–Research and Development Unit for Mechanical and Industrial Engineering (UID/EMS/00667/2013).

References

1. Ahi P, Searcy C (2015) An analysis of metrics used to measure performance in green and sustainable supply chains. J Clean Prod 86:360–377
2. Anand G, Kodali R (2008) A conceptual framework for lean supply chain and its implementation. Int J Value Chain Manag 2(3):313–357
3. Azevedo SG, Carvalho H et al (2012) Influence of green and lean upstream supply chain management practices on business sustainability. IEEE Trans Eng Manag 59(4):753–765
4. Bergmiller GG, McCright PR (2009) Parallel models for lean and green operations. In: Proceedings of the 2009 industrial engineering research conference, pp 43–49
5. Carvalho H, Duarte S, Cruz Machado V (2011) Lean, agile, resilient and green: divergencies and synergies. Int J Lean Six Sigma 2(2):151–179
6. Cash R, Wilkerson T (2003) Greenscor: Developing a green supply chain analytical tool. Technical report, DTIC Document
7. Chen JH, Wu SI (2015) A comparison of green business relationship models between industry types. Total Qual Manag Bus Excell 26(7–8):778–792
8. Dakov I, Novkov S (2011) Assessment of the lean production effect on the sustainable industrial enterprise development. Business: Theory and Practice/Verslas: Teorija ir Praktika 8(4):37–44
9. Dangelico RM, Pontrandolfo P (2015) Being 'green and competitive': the impact of environmental actions and collaborations on firm performance. Bus Strateg Environ 24(6):413–430
10. Dhingra R, Kress R, Upreti G (2014) Does lean mean green? J Clean Prod 85:1–7
11. Duarte S, Cruz-Machado V (2013) Lean and green: a business model framework. In: Proceedings of the sixth international conference on management science and engineering management, Springer, Heidelberg, pp 751–759
12. Duarte S, Cruz-Machado V (2013) Modelling lean and green: a review from business models. Int J Lean Six Sigma 4(3):228–250
13. Duarte S, Cruz-Machado V (2015) Investigating lean and green supply chain linkages through a balanced scorecard framework. Int J Manag Sci Eng Manag 10(1):20–29
14. Dües CM, Tan KH, Lim M (2013) Green as the new lean: how to use lean practices as a catalyst to greening your supply chain. J Clean Prod 40:93–100
15. Dyllick T, Hockerts K (2002) Beyond the business case for corporate sustainability. Bus Strateg Environ 11(2):130–141
16. Evans W, Kelly J (2009) Attaining sustainable savings by going lean and green. In: The 94th annual international supply management conference
17. Galeazzo A, Furlan A, Vinelli A (2014) Lean and green in action: interdependencies and performance of pollution prevention projects. J Clean Prod 85:191–200
18. Gao J, Bansal P (2013) Instrumental and integrative logics in business sustainability. J Bus Ethics 112(2):241–255
19. Garza-Reyes JA (2015) Green lean and the need for six sigma. Int J Lean Six Sigma 6(3): 226–248
20. Govindan K, Diabat A, Shankar KM (2015) Analyzing the drivers of green manufacturing with fuzzy approach. J Clean Prod 96:182–193
21. Initiative GR (2006) Sustainability reporting guidelines, version 3.0. GRI, Amsterdam
22. Labuschagne C, Brent AC, Van Erck RP (2005) Assessing the sustainability performances of industries. J Clean Prod 13(4):373–385
23. Mefford RN (2011) The economic value of a sustainable supply chain. Bus Soc Rev 116(1): 109–143
24. Ng R, Low JSC, Song B (2015) Integrating and implementing lean and green practices based on proposition of carbon-value efficiency metric. J Clean Prod 95:242–255
25. Pakdil F, Leonard KM (2014) Criteria for a lean organisation: development of a lean assessment tool. Int J Prod Res 52(15):4587–4607
26. Pojasek RB (2007) A framework for business sustainability. Environ Qual Manag 17(2):81–88
27. Singh RK, Murty HR et al (2009) An overview of sustainability assessment methodologies. Ecol Indic 9(2):189–212

28. Torielli R, Abrahams R et al (2011) Using lean methodologies for economically and environmentally sustainable foundries. China Foundry 8(1):74–88
29. UN Global Compact and Business for Social Responsibility (2010) Supply chain sustainability, a pratical guide for continuous improvement. http://www.bsr.org/reports/BSR_UNGC_SupplyChainReport.pdf. Accessed 31 Jan 2016
30. United States Environmental Protection Agency (EPA) (2007) The Lean and Environmental toolkit, United States Environmental Protection Agency (EPA)
31. United States Environment Programme (2015) Resource use in the Asia-Pacific—a booklet of infographics. United Nations Environment Programme, Bangkok
32. United Nations Environment Programme (2015) UNEP indicators for a resource efficient and green Asia and the Pacific. United Nations Environment Programme, Bangkok
33. Van den Broek F, Van den Broek-Serlé N (2010) Green supply chain management, marketing tool or revolution?. Breda/Zoetermeer, The Netherlands
34. Verrier B, Rose B et al (2014) Combining organizational performance with sustainable development issues: the lean and green project benchmarking repository. J Clean Prod 85:83–93

Chapter 106
Crowdfunding: An Innovative Approach to Start Up with Entrepreneurship

Muhammad Kaleem Khan, Xiujuan Zhao, Umair Akram, Muhammad Hashim and Ahmad Kaleem

Abstract It is beyond any doubt that getting finance at eve of establishing the creative projects or entrepreneurial businesses is most difficult task. Creator may face difficulty, or failure sometimes, in gathering finance due to lack of relationships with venture capitalists or banks due to lack of sound financial track record or pledge. This paper is to introduce and explain the model of a new form of financing, crowdfunding (CF) for entrepreneurs or project initiator. This research suggests that the field is fragmented and undeveloped. It explains the distinct features and the key players of CF. Crowdfunding—a mechanism, by which an innovative or patronage idea may get into reality by gathering funds from a large number of people through internet, may prove the problem solver for entrepreneurs or creators who don't have enough resources for their dream. Research has also shown business models of crowdfunding and different sources of funding. Based on the available empirical data, we have studied how it can be helpful for capital deficit units and what are its advantages and disadvantages from founder, funder and platform's prospective.

Keywords Entrepreneur · Crowdfunding · Innovation · Venture

M.K. Khan · X. Zhao · U. Akram
School of Economics and Management, Beijing University of Posts and Telecommunications, Beijing 100876, People's Republic of China

M. Hashim (✉)
Faculty of Management Sciences, National Textile University, Faisalabad 37610, Pakistan
e-mail: hasimscu@gmail.com

A. Kaleem
Investment Banking Institute Business School, Melbourne, Australia

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_106

106.1 Introduction

Although an innovative idea for starting a project is very important in the field of entrepreneurship, but if this idea is not supported with required amount of capital, it can never be turned into reality. Usually an entrepreneur faces the problems in collecting necessary capital if he cannot finance project by himself or closed one. It is because he don't have collateral, sufficient cash flows, sound track records of establishing and running a business. Information asymmetry is also a problem that restricts the investors to finance a huge amount in new venture. Either due to insufficient assets to be pledged or unsuccessful attempt to convince investors, many entrepreneurial ventures remain unfunded [14]. An entrepreneur can adopt one option from many types of financing modes. Most of the ideas are financed by entrepreneur's own pocket, savings, credit cards, lending from family members or relatives or friends. Bank and other financial institutions, angel finance and venture capital are also other options. What option an entrepreneur adopts, it depends on circumstances. But reality is that, very few entrepreneurs are successful in getting capital by any mean of seeding capital. Like Pope [17] illustrated that, only three percent entrepreneurs out of thousands are successful.

This paper is to introduce a new method of financing that may prove very helpful to entrepreneurs. In modern era, some initiators have utilized another method of capital generation which stated as "crowdfunding" by tapping the "crowd" instead of specialized investors [6]. By this method, entrepreneurs depend upon internet to directly obtain financial assistance from general public as a substitute of requesting financial help from investors. This technique is widely used in capital generation for not only in starting ventures but, also in projects for specific purposes. Crowdfunding (CF) is a useful tool to assist entrepreneurs in adopting new sources of entrepreneurial projects and managing ventures, ultimately resulting in the development of new businesses. The beauty in such established businesses is that, in general, people are more closely involved in these firms, as an active stakeholders. Most famous example is from Pebble Watch illustrated by Agrawal et al. [3]. This watch was to coordinate with Android or iOS device through a wrist interface. Eric Migicovsky, who already had experience to develop watch for Blackberry, raised US $375K from wealthy angel investors of Silicon Valley. He further needed around $100K to develop this prototype into small production unit. Despite a lot of goodwill and relationships with many angel investors, he found difficulty in raising required capital. On April 11, 2012, he decided to seek help from crowdfunding, purpose was to get seeding finance in petite amounts from crowd through the online platform of Kickstarter, while in return promising crowdfunders a watch for every $120 (approximately) they pledged. Surprisingly, required capital was generated in just two hours. He closed his campaign after rising $10M from 68,929 funders in 37 days.

Like Eric Migicovsky, numerous entrepreneurs have successfully financed their projects through different crowdfunding websites. Mostly websites used for crowdfunding for entrepreneur is, www.kickstarter.com. Since its inception on April 28, 2009 to date, 96,953 (out of 271,043) projects have been funded by the help of

9,970,400 backers. Total amount pledged to be $2,109,885,617. Amount pledged in successful projects is $2.11 billion whereas amount pledged in unsuccessful projects is $253 Million. Till date success rate is 36.58 % (data source: kickstarter stats). "Global crowdfunding experienced accelerated growth in 2014, expanding by 167 percent to reach $16.2 billion raised, up from $6.1 billion in 2013. In 2015, the industry is set to more than double once again, on its way to raising $34.4 billion", says crowdfunding report [8]. BRAJI LCC launched a project on 9th February 2014 to gather US $666,667 to develop Dash C Wireless Smart, In Ear Headphones at Kickstarter. Backers were promised to deliver product for pledging $179 for each dash. By the end of November 14, 2015, 15,998 backers pledged $3,390,551 to help brings this project to life. Another example from Kickstarter project is of M3D, innovator of a 3D printer, who successfully raised $3,401,361 USD with 11,855 backers. Numerous ventures of different sizes have been financed by this manner and CF has become widely acknowledged by the general public. Hundreds of crowdfunding platforms to act as intermediary services have originated to facilitate this phenomenon. Few are worldwide popular (e.g. Kiva, JustGiving, Kickstarter, Rockerhub, Upstat, IndieGoGo, Crowdfunder and Spot-us etc.).

The innermost view for this article is that, if carefully devised, CF could turn out to be an effective substitute to or could be at least harmonize the traditional forms of seed financing mechanisms. Need of the hour is to study it thoroughly and for this very reason it needs close monitoring. But, the problem in this regard is that, this trend is quite new. Due to this reason a little empirical data is in existence and the number of scientific papers is still limited. On the other hand, multiple number of online articles and blog are in existence and the social and print media have also begun to highlight it in news and articles, resultantly popularity of this phenomenon has increased [11]. But still majority of people cannot take a clear picture of what crowdfunding really is.

106.2 Definition of Crowdfunding

In simple words, crowdfunding means tapping a large, geographically dispersed audience, given the name as 'the crowd', for small sums of money to fund a project or a venture. Term "crowdfunding" is derived from better understood term "crowdsourcing", which entails using the "crowd" to acquire ideas, feedback, and solutions to develop corporate activities [6]. It describes the process of outsourcing tasks to a large, often anonymous number of individuals, a "crowd of people" and drawing on their assets, resources, knowledge or expertise. In the case of crowdfunding, the point is to get money. In crowdsourcing, the use of internet makes sense because it does not involve transactions of money. But in crowdfunding, it can be problematic as sometimes it involves transfer of equity and sometimes rewards. This creates legal constraints on crowdfunding as here input is money, not ideas and time. Therefore, most of the platforms offer reward based crowdfunding facilities, and some offers pre specified portion of profit.

According to [15] "Crowdfunding involves an open call, essentially through the Internet, for the provision of financial resources either in the form of donations (without rewards) or in ex-change for some form of reward and/or voting rights in order to support initiatives for specific purposes". Crowdfunding denotes the efforts by entrepreneurs and creators (of projects for any social, political, economic, cultural or scientific etc.) to find their required funds by attracting on relatively small contributions from a relatively large number of individuals using the internet, without standard financial intermediaries. Web 2.0 is basic component in producing crowdfunding platform because it offers two sided interaction of community.

106.3 Literature Review

The literature on crowdfunding is embryonic. Ibrahim and Verliyantina [12] proposed a model of crowdfunding for SMEs of Indonesia. They suggested micro financing through web based platform. The proposed model involves donors/funders, volunteers, field partners, coaches and non-profit organizations that work together in the process of screening, supervising, and managing the use of funds. Davidsona and Poor [9] found that there is some motive that motivates the founder to start another crowdfunding activity. Among these factors, Davidsona and co found that, higher the numbers of increased backers than higher the amount of funds, in the similar manners, goal of that project increases the odds of next project whereas higher pledged to backers, ratio lessen the chances of second project. Article of Tomczak and Brem [19] elaborated crowdfunding models, key players, mode and mechanism of operations. Schwienbacher and Larralde [18] stressed out the need for building a community of crowdfunders which enjoys additional utility from their participation. Allison, Davis, Short and Webb [5] described the cognitive evaluation theory to determine how microlenders respond to both intrinsic and extrinsic cues in the case of entrepreneurial ventures.

Ahlers, Cumming, Gunther and Schweizer [4] found that retaining equity and providing more comprehensive information about risks can be interpreted as effective signals that can increase the likelihood of funding success. Furthermore, governance structure i.e. proper board structure and more highly qualified board members can develop attraction for investors as well as accelerate the speed of capital rising. Colombo, Franzoni and Rossi-Lamastra [7] study the factors of the success of crowdfunding initiatives by focusing on the internal social capital theory. Study also briefly discuss self-reinforcement theory that, illustrates, if a campaign receives contributions in earlier days, it is more likely to be successful. This study tried to identify the reason of this "success breeds success" pattern. They checked this by quantitatively documenting the capital raised and number of backers at early days of project and found that it is the capital raised in early days that trigger the reinforcement behavior. Moreover they emphasized on internal social capital which is to be emerged by crowdfunding platform and flourished by positive behavior by all the stakeholders in this crowd. They illustrated that, internal social capital appears stronger in magnitude than external social capital.

Ajay Agrawal, Catalini and Goldfarb [1] examined the role of distance in crowdfunding. They differentiated local and distant funders. They found that investment patterns over time are not strongly related to the geographic distance between artist and funder. They recognized, there are several reasons that the geographic distance between artists and potential funders might matter, such as spatially correlated tastes, monitoring progress, search frictions, and reputation effects related to trust and the risks associated with fraud or managerial incompetence. Mollick [16] suggested that crowdfunding projects mostly succeed by narrow margins. Moreover, high quality projects, large social network, projects reflecting cultural taste of geographical component, and nature of population in which founder operate are related with success of project. By using Founders of projects also try to fulfill obligations of funders. Delays in delivering the promises are more with large projects. Valanciene and Jegeleviciute [20] explained crowdfunding phenomenon is based on the Content, Context, Linkages and Stakeholders logics. By using descriptive approach, they concluded that value is created on the basis of performing roles of all the stakeholders.

106.4 Key Players in Crowdfunding Phenomenon

There are three main players in crowdfunding process i.e. initiator or entrepreneur, crowdfunding platform or intermediary and funders. Intermediary, which is called platform, that serves as a matchmaker between founders and funders. After that, there are the fundraisers (creators, founders, entrepreneurs, initiators and others) who need to gather funds via a crowdfunding platform. These are the individuals who are fund deficits. CF platform helps the founders in getting direct access to the finance market and to gather required capital only from truly interested contributors. Lastly, there are the crowdfunders (investors, lenders, supporter, donors) themselves. They are stated as ‘crowd’ from the term crowdfunding, who decide to financially support these projects, bearing a risk and expecting a certain payoff [10].

Crowdfunding platforms are usually web and software based. They facilitate neutrally to both sides i.e. entrepreneurs and crowdfunders. Primary function of these platforms are to facilitate interaction between entrepreneurs and crowdfunders by presenting projects and providing ways to administer pledges. But there are also some platforms that, go some extra miles by organizing public relations for initiators, making arrangements with micro-payment providers or financial institutions [11]. What is motive for these platforms for performing their role in bridging initiators and individuals? Most of the websites do it for money. Like Kickstarter charges founders 5 % fee of total fund gathered but charges individual investors nothing. Fee of Indiegogo is 4 % of the money raised from successful projects and 9 % if a fundraising goal is unmet and again investors pay nothing.

Although, literature emphasize on these three players only [11], but we cannot ignore some supporting roles of different agents. Category of these agents varies from

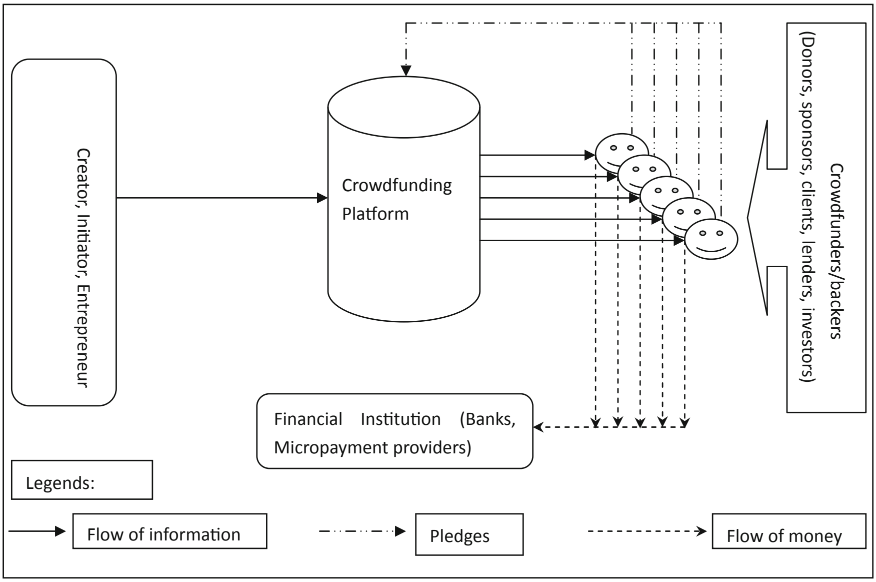


Fig. 106.1 Players in crowdfunding phenomenon

nature of model of crowdfunding, but role of financial institutions is most common in all. This financial institution may be a bank or micropayment provider. There are some crowdfunding platforms that manage the funding amounts by their own. But, mostly they out source this function to some financial institutions like bank or micropayment provider (Fig. 106.1).

106.5 Models of CF

Before knocking a crowdfunding market, entrepreneur must knew about the types of his or her project. S/He must know which type of project fits in what type of crowdfunding model. On global level, following models of crowdfunding exist.

106.5.1 Donation Based

This model of crowdfunding is based upon philanthropic approach. Purpose of these types of projects are to serve humanity and to do work for a social cause. Usually crowdfunders do this type of funding for self actualization, satisfaction and for being the part of welfare society, and don't expect any monitory reward. Nepal Youth Foundation receives 950 donations from more than 580 donors by GlobalGIving.

They use this donation to rescue indentured girls, send them to their families and provide families with other sources of income to replace the income from selling their daughters, and make arrangements of education for these girls.

106.5.2 Reward Based

Some crowdfunders also sponsor some project that is beneficial for the society in the areas of health care, development of remote areas, poverty alleviation, education, general charity, public research projects, and open source software. Although there is no expectation of any type of reward when crowd funder finance a public welfare project, but some initiators give some rewards as paying thanks to crowdfunders. These rewards may be just thank you memo, T shirts, autograph of celebrity, positioning the contributor's name on the cover of a documentary, film or DVD, meeting with celebrity or production [11].

Pre purchase: It is very close of reward based model of CF, that's why most of the researchers discuss it under reward based model. In pre purchase, entrepreneurs request customers to order the product before it comes to in existence. Purpose is to collect the required capital for start up. Due to this model, crowdfunders and ordinary customers get the product on different prices. Usually entrepreneurs gives special discount to the customers who order the products before its existence, thereby helping to founders to produce that products [11]. This type of contribution helps the founders to write a book, to make a film or music album or other entertainment segment, to produce innovative software and inventions along with unique services. JamKazam has uploaded the project of JamBlaster, a device that will play live in sync with other musicians from different locations over the Internet. In return crowdfunder will get JamBlaster earlier if they pledge $199 [13].

106.5.3 Equity Based

Crowdfunders invest in ventures and receive some possession or equity-like shares. This is also called investment based crowdfunding. This alternative micro-investment is considered to be the most complex model among crowdfunding models. This is an investment model, in which funders become investors by investing the equity; in return they achieve share in the venture, dividends, capital gain and/or voting rights. We also add profit sharing crowdfunding in equity based model in which entrepreneurs request individuals to finance a project and in return they get a share of future profits or equity securities. Questol, a social enterprise based in Guatemala City, aims to offer clients the flexibility to consume electricity based on hourly, daily, weekly, or monthly installments. For this purpose, they have to install patent pending technology on gird. The estimated budget for this project is $1 M. The

Table 106.1 Existing models of crowdfunding

CF model	Description	Examples
Reward based	Founder receives contributions from crowdfunders and rewards them with early issue of product or anything else	Kickstarter, Indiegogo, RocketHub, Verkami, Pozible
Donation based	Founders get donation from Crowdfunders for the start up of community benefit project	GlobalGiving, JustGiving, Causes, FundRazer
Equity based	Founder offers ownership or equity to in return for their investment	GrowVC, DragonInnovation, Upstart, crowdfunder
Lending based	Founder borrow money from Crowdfunders and give them future repayment of a principal with or without interest	Kiva, Zidisha, lendingclub, Propser

current investors of Questol, include the Inter-American Development Bank, Tom Chi, Global Partnerships, Matias de Tazanos, Eleos Foundation, and private investors.

106.5.4 Lending Based

Contributors may become creditor, if, they lend in the expectations of future repayment of a principal with or without interest. Revenue sharing model is another substitute of long-term lending. Creditors gives a risk-bearing loan to project but do not receive regular interest payment, rather receives an amount having a agreed portion of profit from venture at the defined end of the lending period, this amount could be a multiple of the original loan but it could be only in the case of bad performance—also be nothing [11]. Kiva, a lending based crowdfunding website, was founded in 2005. Since its inception, it has succeeded to facilitate lending amount of $786,932,900 from 1,357,654 lenders. Repayment rate is about 99 % (Table 106.1).

106.6 Advantages of Crowdfunding

106.6.1 Founders Prospective

Demand Generation: Crowdfunding is used to know about the demand of the product in case of pre-sale type of crowdfunding.

Analysis of all previously created projects: But crowdfunding creates a useful window for the study of nascent entrepreneurial ventures, as both failed and successful projects are represented. All types of new entrepreneurial ventures can be compared and studied.

Matching Principle: Founder's need is matched with funder's willingness to fund. Founder is able to get finance from a funder who is deeply involved in the project of founder. In off line financing module, financing decision is primarily dependent upon the location of entrepreneurs. Like in case of Sellaband, average distance between creator and financier is about 3000 miles measured by Kiva [2].

Feedback to improve product or project: Crowdfunding also serves as the source by which founder can get the feedback of his project idea and get suggestions for improvements in their projects. Like in project of developing a unique product, people can give ideas of a specific application in the products that may increase value of product.

106.6.2 Funders Prospective

Motives of funders to fund a project are heterogeneous. They may invest for humanitarian cause, welfare, political or in the hope of some reward, stake and fix return. In equity crowdfunding, funders get ownership and in lending crowdfunds, funders get fix amount of interest over their funds. Similarly in reward based funding projects, funders get some sort of reward. Like their name written on the product, acknowledgements, being credited in a movie, being part of input providers in manufacturing of a valuable product and having the opportunity to meet producers. In case of preselling, funders may get the product in early days of releasing. Philanthropy is among those key factors which play significant role in main crowdfunding platforms. Some funders support a project without expectation of any type of monitory reward like pre buying, equity or fixed return of lending. Equity stakes in crowdfunding, legalized after approval of Jumpstart Our Business Startup Act (JOBS) in april 2012, has become legal stake in equity. Funders can become investors by crowdfunding activity. As before this Act, equity crowdfunding had no legal status in legislation, investments in crowdfunding were negligible.

106.6.3 Platform Prospective

Most of the platforms work for profits. Usually they charge some percentage of funding amount as service fee. Platform has the role in bridging the gap between entrepreneurs and funders. These platforms have objectives to increase the numbers of successful projects. On the other hand, they also try to offer innovative and workable projects to funders and provide opportunity of investment. They also act as a platform to develop philanthropic habits in society. These patronage deeds help the deceased section of the society. They are responsible to develop smooth flow of money from funders to entrepreneurs and project initiators.

106.7 Disadvantages of Crowdfunding

106.7.1 Funders Prospective

Disclosure Problem: other than the cases of crowdfunding, like generation of capital from home, relatives or venture capitalist, founder does not make his ideas public, so innovation ideas remain secret from general public. But in case of generating capital through crowdfunding, ideas become public and it is no more secret. Although this is not a problem for philanthropic, charity and patronage types of projects, but really a serious issue for innovative idea of product or entrepreneurial business.

Lack of professional support: In the case when angel investors or venture capitalists provide capital to a project, they also provide some extra benefits for example professional suggestions to establish successful business in the market where entrepreneurs operating or intention to operate. Non professional fund providers cannot provide these types of benefits to founders.

Increased cost of Investors Handling: In case of financing by crowdfunding, investor management cost gets increase. As illustrated by Max Salzberg [21], who succeeded in raising $200K on Kickstarter to develop an open-source alternative to Facebook, described his team's experience as "so consumed with things like answering emails and making T-shirts for their contributors that they had little time to build the software".

Incompetent Founder: Sometimes, idea seems very strong and has the potential to attract a lot of funders, but on the other hand, founder has not competency to convert that idea into the reality successfully. As discussed by Mollick [16]. From sample of 471 projects enlisted on Kickstarter, Mollick found that output of more than 50 % projects is delayed.

Threat of fraudulent projects: Overoptimistic investor can be suffered by frauds also. By analyzing about 48,000 projects, Mollick [16] concluded that fraudulent cases were rare. 3 projects were found to be refund and 14 projects apparently stopped responding to the investors. But chances of fraudulent projects still exist.

106.8 Conclusion

Entrepreneurs and project creators, who cannot finance their venture or project by their own pockets, friend and family, rush towards venture capitalist and angel investors. But, if still they are unable to get funded, then their idea remains an unfulfilled dream only. Crowdfunding is a way of gathering finance that does not require your strong personal relations or your ability to pledge. "Crowdfunding involves an open call, essentially through the Internet, for the provision of financial resources either in form of donations (without rewards) or in ex-change for some form of reward and/or voting rights in order to support initiatives for specific purposes" [15]. By crowdfunding, entrepreneurs may tailor their funding campaign better than on standardized platforms. This enables entrepreneurs to offer a large variety of compensation to the crowd, such as opportunity of active involvement in terms of time and expertise.

Entrepreneurs and crowdfunders choose a crowdfunding model according to their requirements. These models vary from donation based, reward based, pre-sale, equity based and lending based. Both, the crowdfunders and entrepreneurs or creators have more advantages of employing crowdfunding than disadvantages. CF is on the verge of becoming an important complement of seed financing source of innovative businesses and projects containing patronage ideas. Its importance is increasing because, up to some extent, it lessens the difficulties of traditional ways of financing entrepreneurial ventures like venture capital, loan from bank, angel financing etc. According to [11], The reason for excelling the CF among all the sources of seeding finance may be as "entrepreneurial ventures that have difficulties raising capital from traditional sources like bank loans, angel capital, VC, state promotion and others because they appear too exotic, too innovative to be understood, too complex, too crazy, too risky or which are, simply, poorly presented".

Future research should answer many questions like, what are the successes or failure factors of crowdfunding projects, how different factors affect on crowdfunders? Whether crowdfunders can be involved in the decision regarding product development or can participate in voting rights? The extent to which platforms increase the chances of success of crowdfunding initiatives or solve asymmetric information issues, how risk is minimized? How geography affect it?

Acknowledgments The authors want to extend their gratitude towards the Editor and the anonymous Reviewers for their indispensable and valuable suggestions and comments that improved the quality of the paper significantly.

References

1. Agrawal A, Catalini C, Goldfarb A (2015) Crowdfunding: geography, social networks, and the timing of investment decisions. J Econ Manag Strateg 24(2):253–274
2. Agrawal AK, Catalini C, Goldfarb A (2011) The geography of crowdfunding. Technical report, National Bureau of Economic Research
3. Agrawal AK, Catalini C, Goldfarb A (2013) Some simple economics of crowdfunding. Technical report, National Bureau of Economic Research
4. Ahlers GK, Cumming D et al (2015) Signaling in equity crowdfunding. Entrep Theory Pract 39(4):955–980
5. Allison TH, Davis BC et al (2015) Crowdfunding in a prosocial microlending environment: examining the role of intrinsic versus extrinsic cues. Entrep Theory Pract 39(1):53–73

6. Belleflamme P, Lambert T, Schwienbacher A (2014) Crowdfunding: tapping the right crowd. J Bus Ventur 29(5):585–609
7. Colombo MG, Franzoni C, Rossi-Lamastra C (2015) Internal social capital and the attraction of early contributions in crowdfunding. Entrep Theory Pract 39(1):75–100
8. Crowdsourcing (2015) Global crowd funding market to reach $34.4b in, 2015, predicts massolution's 2015cf industry report. Technical report, Crowdsourcing
9. Davidson R, Poor N (2016) Factors for success in repeat crowdfunding: why sugar daddies are only good for bar-mitzvahs. Inf, Commun Soc 19(1):127–139
10. Fisk RP, Patrício L et al (2011) Crowd-funding: transforming customers into investors through innovative service platforms. J Serv Manag 22(4):443–470
11. Hemer J (2011) A snapshot on crowdfunding. Technical report, Working papers firms and region
12. Ibrahim N (2012) The model of crowdfunding to support small and micro businesses in Indonesia through a web-based platform. Procedia Econ Financ 4:390–397
13. Kickstarter J (2015) The ultimate smartphone accessory for musicians
14. Kirsch D, Goldfarb B, Gera A (2009) Form or substance: the role of business plans in venture capital decision making. Strateg Manag J 30(5):487–515
15. Kleemann F, Voß GG, Rieder K (2008) Un (der) paid innovators: The commercial utiliza-tion of consumer work through crowdsourcing. Sci, Technol Innov Stud 4(1):5–26
16. Mollick E (2014) The dynamics of crowdfunding: an exploratory study. J Bus Ventur 29(1): 1–16
17. Pope N (2011) Crowdfunding microstartups: It's time for the securities and exchange commission to approve a small offering exemption. University of Pennsylvania Journal of Business Law
18. Schwienbacher A, Larralde B (2010) Crowdfunding of small entrepreneurial ventures. Handbook of entrepreneurial finance. Oxford University Press, Oxford (Forthcoming)
19. Tomczak A, Brem A (2013) A conceptualized investment model of crowdfunding. Ventur Cap 15(4):335–359
20. Valanciene L, Jegeleviciute S (2014) Crowdfunding for creating value: stakeholder approach. Procedia-Soc Behav Sci 156:599–604
21. Wortham J (2012) Success of crowdfunding puts pressure on entrepreneurs, vol 17. The New York Times

Chapter 107
Empirical Research on Equity Incentives for Executives of Different Industries and Dividend Policy

Chaojin Xiang, Qianyao Li and Xiaoyi Qu

Abstract This article selected panel data of Chinese listed companies from 2009 to 2013, and carried out empirical research on interaction between equity incentives for executives of Chinese listed companies in different industries and their cash dividend policy. We reached the following conclusions: the correlation between equity incentives and cash dividend policy is prevalent in all companies, but whether it is positive or negative varies in different industries; the tendency and degree of equity incentives of each industry have the same impact on dividend payout ratio. Through further research we also concluded that the impact from equity incentives on cash dividends will be weakened if the management is over empowered; for Chinese listed companies, the dividend policy is significantly affected by equity incentives when the management has little power, and the direction of effect varies in different industries. The conclusions of this paper provide experience and evidence for improvement of incentives and dividend policies in Chinese listed companies.

Keywords Equity incentives · Cash dividend · Power of management

107.1 Introduction

The equity incentive policy of China came out quite late compared with that of western countries. It was by the end of 2005 when China Securities Regulatory Commission issued Administration for Equity Incentives of Listed Companies that the equity incentive policy had been put into effect. At the very beginning, there were few companies that implemented this policy without canceling it afterwards. But after 2008 Financial Crisis, the number of listed companies that implemented equity incentive policy has increased steadily year by year as a result of the further enhancement of relevant regulation. The main targets of equity incentive are the senior management and the core technical staff, and the main ways of incentive

C. Xiang (✉) · Q. Li · X. Qu
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 347086364@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_107

include Stock Option, Restricted Stock and Stock Appreciation Right. The purpose is to align the targets' interest with corporate benefits, and to mitigate the agency problem between the management and shareholders.

Dividend policy is a very important financial decision for companies. Because Chinese capital market is young and immature, the cash dividend policy of listed companies has many problems such as low dividend rate, poor dividend continuity, poor dividend distribution, etc. These problems have been incurring much criticism from investors and the public in that the interests of minority shareholders are unable to be protected. The decisions of dividend policy should have been taken by Board of Directors (BOD) and Annual General Meeting (AGM). However, the phenomenon is quite common in China that the chief executive and the board chairman is the same person, so the senior management designated as the incentive target also participates in dividend policy making. We can infer from above that the changing of executives' remuneration packages by equity incentive plan may drive them to make decisions that maximize their equity gains for their own good. Hence, we need to conduct further researches on: whether the equity incentive plans can meet its objective; whether the relationship between equity incentives and dividend policies varies in different industries; which roles the management plays, and so forth.

107.2 Literature Review

The original intention of equity incentives is to alleviate conflicts of interest between the management and shareholders, so the most direct effect of equity incentives would be reflected on the corporate performance. Foreign scholars' researches have yielded fruitful results on equity incentives. Mehran [9] argued that there is positive correlation between equity incentives and corporate performance, for the reason that equity incentives could motivate the management to work hard and make decisions consistent with corporate benefits, and therefore improve the corporate performance. Chinese scholars Zhou and Sun [15] reached a similar conclusion using the data of Chinese listed companies by the end of 2001.

With further development of incentive system and deeper study on this field, scholars started to link the equity incentives with dividend policies. Over 95 % executives from American companies carry out stock options which are not dividend protected, which means that the exercise price of their stock options has been determined when they are granted and will not be adjusted by ex-equity or ex-dividend afterwards. This implies that the management would not be willing to pay any cash dividends to shareholders as this will cause devaluation on their stock options with the falling of share price. In the contrary, the stock options in China are dividend protected, so the option price will be adjusted by ex-equity, such as dividend distribution and allotment. The adjusted equation is: $P = P_0 - V$, P_0 is the exercise price before adjust; P is the adjusted exercise price; V is the amount of cash dividend. In this way the payout of cash dividend will not lead to devaluation on stock options.

American scholars have conducted many researches on the relationship between equity incentives on the senior management and the corporate dividend policies, a large proportion of which focused on the impact of stock options on cash dividend and stock repurchase. It is clear that rational managers would prefer stock repurchase which could lead to increase of share price rather than cash dividend which would result in impair menton their options, considering the nature of stock options they hold. There is relevant conclusion of empirical research in support: companies that conduct equity incentives are unwilling to pay cash dividend. We can infer the situations in China (the stock options are dividend protected). Firstly, the payout of cash dividend will not cause devaluation on stock options, and therefore companies with more spending on equity incentives are more likely to pay cash dividend. The executives can not only obtain the cash dividend but also circumvent the decline of share price from investment failure. Secondly, the executives who are granted restricted stock would also tend to pay cash dividend because they would prefer the real gains from cash dividend which does not vary with the share price to the uncertainty of the future share price.

Liljeblom and Pasternack [6] conducted empirical research on Finnish listed companies and found that the equity incentive is positively correlated with cash dividend under the dividend protected system. In fact, many Chinese scholars also reached the same conclusion. Xiao and Yu [11] targeted at Shanghai and Shenzhen's listed companies which carried out equity incentive plans in between Jan, 1st, 2006 and Jun, 30th, 2011. They found that the cash dividend payment of animated companies was much higher than that of unanimated companies since the year before they carried out equity incentive plans. Hu and Zhang [5] used Relogit model and Multivariate Linear model in their empirical analysis and found that the animated companies were more inclined to pay cash dividend and their dividend payment was higher than their unanimated counterparts. After eliminating the endogenous problem by establishing simultaneous equations, the conclusion above was still correct. In the same year, Xu [12] reached the same conclusion after taking inside manipulation into account. He also found that the dividend payout had the most significant correlation with the capitalization of capital reserve, and some animated companies paid excess dividend.

Equity incentives were designated to mitigate the agency problem. The management has dual roles after being granted incentives-director and future shareholder. They should have been motivated to act for maximizing shareholder benefits. However, Zhang and Ruan [14] argued that the management was unwilling to pay dividend when the company had a large amount of cash flow. There is serious dividend agency problem in this situation, as the benefits obtained through consumption at their authority and individual power are much greater than those of equity incentives. Equity incentives then become a means of seeking personal gains and deteriorate the agency problem. On the other hand, the management under the background of equity incentives should focus on the long-term objectives of company. They would not tend to use the cash flow for dividend, but invest them to support further development. To meet the vesting conditions and maximize their reward on equity, executives have strong motivation to work hard and add value for their companies. In this way the executives may not prefer paying cash either if there is cash flow restructuring. Lv and Zhang [8] found that the companies which implemented equity incentive plans tended to reduce cash dividend compared with their counterparts, and their dividend payout ratio was even lower than before. Luo, Ran and Du [7] did empirical research on the interaction and endogenous relationship between equity incentives and investment policies by studying penal data of Chinese listed companies from 2002 to 2005. They found that the investment was positively correlated with equity incentive, which suggested that the animated management would use the retained earnings to do more investment rather than pay cash dividend. We may infer that there is negative correlation between equity incentive and cash dividend.

In Chinese corporate governance, sometimes the chief executive is also the chairman of the board and there fore the management can manipulate gains from equity incentives by all means. Aboody and Kasznik [1] found that executives could manipulate the share price by controlling the granting time of equity incentives, publishing time of good news and even the content of financial restatements. The inference that equity incentives could deteriorate the agency problem may be confirmed. Wu and Wu [10] collected information of the top three executives' remuneration in Chinese listed companies from 2004 to 2008, and they studied the relationship between executive remuneration and corporate performance, power of management, government regulation and the agency cost. Their results verified that the executives have apparent self-serving behaviors in formulating their remuneration package, and these self-serving behaviors have reduced and even eliminated the remuneration stimuli. When the management has unfettered power, the cash dividend return has nothing comparable with the benefit from the consumption at their authority and individual power. So we could infer that the power of management would weaken the correlation between equity incentive and cash dividend.

To sum up, the existing literature does not reach an agreement on the relationship between equity incentives and dividend policies. The domestic and overseas differences can be partly explained by the dividend policy system, but there are still some problems in the previous researches: (1) Most Chinese scholars only considered the number of stock option, but with the development of equity incentive policies, more and more companies have started to adopt restricted stock as their means of stimuli, so the restricted stock cannot be ignored. (2) Almost all the researches were conducted by setting dummy variables based on the industry as a whole, and therefore lack thorough study from industrial characteristics. (3) Most domestic literature did not adopt panel data method to process the study samples. However, panel data have lots of sample points which can increase the flexibility and reduce collinearity between independent variables and thus improving the efficiency of estimation. (4) Many researches did not take into account the common phenomenon in Chinese listed companies that the chief executive and the chairman could be the same person. It is incomplete to ignore the power of management when studying the relationship between equity incentives and dividend policies.

This article selected study samples from Chinese listed companies that published equity incentive plan and did not cancel it afterwards between 2009 and 2013, and adopted panel data method to process data and analyze the correlation between equity incentives and dividend policies based on industrial characteristics. We commenced the study on equity incentives from the implementation of incentive plans and the degree of the equity incentives, at the same time we both considered the share option and restricted stock as means of equity incentives. Addition to that, we classified the level of management power and took the method of grouping and contrasting to make our description more explicit to show the influencing mechanism behind the relationship of these two factors. In conclusion, our research has some improved parts which are more valuable than the previous researches.

107.3 Status Analysis of Equity Incentives and Dividend Policy

107.3.1 Sample Selection

After China Securities Regulatory Commission issued Administration for Equity Incentives of Listed Companies on Dec, 31, 2005, relevant laws and regulations have been gradually enhancing and the equity incentive system has become better developed. According to the statistics of Bi [2] about relevant researches on equity incentives in China by 2014, most of which focused within 2–3 years after 2006. But at that time the equity incentive system was immature, and the capital market was seriously attacked by the 2008 Financial Crisis. There were few companies that implemented this plan, which directly led to a limited sample, making it difficult to reach representative conclusions on the effectiveness of equity incentives.

In terms of this condition, we selected the recent five years' data from Jan, 1, 2009 to Dec, 31, 2013 as our samples, considering that they were under new regulation background when the development of equity incentives has been on track. We also excluded data under following conditions: (1) financial companies and B-share companies; (2) the profit for the year attributable to parent was negative; (3) the retained earnings for the year was negative; (4) the free cash flow per share was negative. In terms that every industry has its own features and different equity incentive and cash dividend policies, we targeted at industries that have relatively more implemented companies. Finally, we obtained observations of 135 companies from 7 industries during 5 years. According to the classification of industry from Wind Database, these included 17 material II companies, 15 real estate companies, 12 consumer durables and clothing companies, 10 software and service companies, 11 drug, biotechnology and bioscience companies, 28 capital goods companies and 14 technology and hardware companies. The data of executives' remuneration was from Wind Database and other data was from CMSAR Database. The statistic software we adopted was STATA 13.0.

107.3.2 Variable Selection

We took Bergstresser and Philippon's method (2006), which was the same as Ye and Zhang's [13], using the proportion of shares and options to total remuneration to reflect the level of equity incentive. We referred to the existing literature of Guo [3]; Han, Lv and Li [4] found that the main factors which affect the dividend payout include return on earnings, company size, executive remuneration, executive share holding ratio and dividend capacity.

Definitions of all variables are shown in Table 107.1.

Table 107.1 Definition of variables

Variable attribute	Variable name	Variable symbol	Variable explanation
Dividend variable	Dividend payout ratio	Dpr	$[\sum(\text{pdps} \times \text{bd})/\text{rp}] \times 100\,\%$
Equity incentive variable	Whether or not implementation of equity incentive	eso1	The implementation of equity incentive program referred to as 1, otherwise 0
	Equity incentive degree	eso2	See appendix
Company characteristic variable	Return on equity	Roe	Rp/cse
	Company size	Size	The natural logarithm of the company
	Executive remuneration	Reward	ln(reward + 1)
	Executive share holding ratio	Eas	
	Time to market	Time	The number of companies listed on
	Dividend capacity	Capacity	See appendix
Power variable	Power of management	Mr	If the management plays the double roles of chairman and executive record is 1, otherwise 0
Non-study variables	Pre-tax dividend per share	Pdps	Variable symbols appear explained above
	The basic dividend	Bd	
	Retained profits	Rp	
	The company shareholders' equity	Cse	

$$\begin{aligned} \mathrm{eso2}_{it} = {} & (0.01 \times \mathrm{price}_{i,t} \times \mathrm{option}_{i,t})/[0.01 \times \mathrm{price}_{i,t} \times (\mathrm{option}_{i,t} \\ & + \mathrm{share}_{i,t}) + \mathrm{salary}_{i,t}], \end{aligned} \tag{107.1}$$

where $\mathrm{price}_{i,t}$ is the share price on the last trading day for that year proclaimed by Equity Incentive Draft; $\mathrm{share}_{i,t}$ is the number of executive's share holding for that year; $\mathrm{salary}_{i,t}$ is the amount of executive's total salary and bonus. The equation indicates that the equity inventive is measured by the effect on executive's remuneration when the company's share price rises 1 %. This effect on stock options and restricted stock is the same. So $\mathrm{option}_{i,t}$ here is the total number of stock options and restricted stock.

$$\mathrm{capacity} = \{\mathrm{capspls} + \max[0, \max(0, \mathrm{ernspls} - 0.25\mathrm{cap}) + \mathrm{ernpy}]\}/\mathrm{cap}, \tag{107.2}$$

where capspls is capital reserve; ernspls is surplus reserve; ernpy is retained earnings; cap is total equity.

107.3.3 Status of Equity Incentives and Cash Dividends

We used the data of 135 listed companies that carried out equity incentives between Jan, 1, 2009 and Dec, 31, 2013 to analyze: whether the equity incentives have been implemented (in each year); whether the cash dividend has been paid; the degree of incentives; the payout ratio of cash dividend.

As we can see from the Table 107.2, in the sample session there are huge differences on the number of companies which implemented equity incentives between each industry. Capital goods, material and real estate industries are more in favor of equity incentive plans, while real estate, drug, biotechnology and bioscience, and technology and hardware industries have a higher level of incentive. Additionally, other industries show an upward trend in the number of the animated companies and in the average level of equity incentives. As it is shown in Table 107.3, most samples that carried out equity incentives have paid cash dividends. The dividend payout ratio of technology and hardware industry is relatively high, whereas that of consumer durable and clothing industry grows rapidly with time. Other industries also see an upward trend in dividend payout ratio with time. After combining Tables 107.2 and 107.3 we found that the degree of equity incentive and the amount of cash dividend of technology and hardware industry are both fairly high, but whether there is statistic correlation between these two factors, we will do further research in Sect. 107.4.

Table 107.2 Status of equity incentives

Industry	Number of companies	The percentage of the companies that carried out equity incentives accounted for the study sample					The mean level of equity incentives				
		2009 (%)	2010 (%)	2011 (%)	2012 (%)	2013 (%)	2009	2010	2011	2012	2013
Material II	17	29.4	41.2	58.8	70.6	94.1	0.153	0.194	0.199	0.297	0.272
Real estate	15	20	46.7	66.7	80	80	0.129	0.283	0.41	0.403	0.412
Consumer durable and clothing	12	16.7	25	41.7	66.7	91.7	0.101	0.18	0.296	0.313	0.395
Software and service	10	0	30	70	100	100	0	0.106	0.161	0.133	0.132
Drug, biotechnology and bioscience	11	18.2	27.3	63.6	54.5	81.8	0.066	0.12	0.253	0.258	0.447
Capital goods	28	14.3	28.6	57.1	67.9	85.7	0.044	0.102	0.204	0.264	0.275
Technology and hardware	14	14.3	35.7	64.3	78.6	92.9	0.071	0.126	0.298	0.292	0.412

Table 107.3 Status of cash dividends

Industry	Number of companies	The percentage of the companies that paid the cash dividend					The average dividend payout ratio				
		2009 (%)	2010 (%)	2011 (%)	2012 (%)	2013 (%)	2009	2010	2011	2012	2013
Material II	17	76.5	82.4	76.5	82.4	82.4	0.274	0.227	0.256	0.46	0.271
Real estate	15	93.3	80	73.3	100	80	0.223	0.196	0.263	0.233	0.2
Consumer durable and clothing	12	58.3	66.7	66.7	91.7	83.3	0.169	0.199	0.193	0.414	0.326
Software and service	10	70	90	100	80	100	0.26	0.209	0.285	0.277	0.445
Drug, biotechnology and bioscience	11	90.9	90.9	100	81.8	90.9	0.229	0.204	0.294	0.244	0.292
Capital goods	28	82.1	89.3	78.6	89.3	92.9	0.237	0.198	0.199	0.308	0.238
Technology and hardware	14	100	78.6	92.9	85.7	92.9	0.57	0.376	0.347	0.372	0.338

107.4 Further Empirical Test

In the last part, we made an overall status analysis of equity incentive and cash dividend under the background of Chinese listed companies. In this part we will make regression analysis to research more deeply on the relationship between equity incentive tendency, equity incentive degree, dividend payout ratio and the power of management.

107.4.1 Research Hypothesis

The correlation between equity incentive and cash dividend will vary in different industries because of their different size, rate of return, cash dividend capacity and the power of management. Therefore, we proposed following hypotheses:

Hypothesis 1. The equity incentive and the dividend payout ratio show a significant correlation, but whether the correlation is positive or negative depends on the specific industry.

Hypothesis 2. The variable of whether a company implements equity incentives and the variable of the level of equity incentives have the same effect direction on dividend policies.

Hypothesis 3. If the management has unfettered power, the correlation between equity incentive and dividend policy will be weakened.

107.4.2 Model Design

We used the panel data method and designed our model based on existing literature and practical research of Chinese listed companies. The practical regression model is as followed:

Model 1: equity incentive tendency model

$$\begin{aligned}\mathrm{dpr}_{i,t} = {} & \alpha_0 + \alpha_1 \mathrm{eso1}_{i,t} + \alpha_2 \mathrm{roe}_{i,t} + \alpha_3 \mathrm{size}_{i,t} + \alpha_4 \mathrm{reward}_{i,t} \\ & + \alpha_5 \mathrm{eas}_{i,t} + \alpha_6 \mathrm{time}_{i,t} + \alpha_7 \mathrm{capacity}_{i,t} + \alpha_8 mr_{i,t} + \varepsilon_{i,t}.\end{aligned} \tag{107.3}$$

Model 2: equity incentive degree model

$$\begin{aligned}\mathrm{dpr}_{i,t} = {} & \beta_0 + \beta_1 \mathrm{eso2}_{i,t} + \beta_2 \mathrm{roe}_{i,t} + \beta_3 \mathrm{size}_{i,t} + \beta_4 \mathrm{reward}_{i,t} \\ & + \beta_5 \mathrm{eas}_{i,t} + \beta_6 \mathrm{time}_{i,t} + \alpha_7 \mathrm{capacity}_{i,t} + \beta_8 mr_{i,t} + \varepsilon_{i,t}.\end{aligned} \tag{107.4}$$

107.4.3 Descriptive Statistic

We took material industry as an example to show variable descriptive statistics. Table 107.4 variable descriptive statistics of material industry.

From Table 107.4, we can see that the average dividend payout ratio of material industry is 0.297; the mean value of equity inventive is 0.595; return on earnings is 0.097; cash dividend capacity is 0.527; average listed time is 7.118; average company size is 22.119; the average of executive share holding ratio is 5.858.

107.4.4 Empirical Results Analysis

As we adopted the panel data, the first and foremost for us was to choose the best panel data model. We used F Test to make a choice between Mixed OLS Model and FE Model, and we used LM Test to make a selection between Mixed OLS Model and RE Model. Then we used Hausman Test to compare the significance of FE Model with that of RE Model.

Since the panel data included both time series data and sectional data, we had to test autocorrelation of sequence and heteroscedasticity to avoid deviation of regression results. So we used Wooldridge Test to test autocorrelation of sequence and Modified Wald Test to test heteroscedasticity between groups. To eliminate the effects of heteroscedasticity and autocorrelation, we could use FGLS, TSLS or GMM Model. Considering that every model has its own requirement for data (for example, GMM Model is only suitable for the large sample and become invalid for the small one), finally we chose the most suitable model (among Mixed OLS, FE, RE, GMM, TSLS and FGLS Model) to carry out our empirical analysis in accordance with the panel data in different industries.

We took material industry as an example to show the regression results of Model 1 and Model 2. As we can see in Table 107.5, the companies that implemented equity incentive under the 5 % level show a stronger will to pay cash dividend, and the 5 %

Table 107.4 Variable descriptive statistics of material industry

Variable	N	Mean	Max	Min	Sd	Variance
Dpr	85	0.297	2.421	0	0.319	0.102
eso1	84	0.595	1	0	0.494	0.244
eso2	85	0.223	0.999	0	0.358	0.128
Roe	85	0.097	0.625	−1.108	0.165	0.027
Capacity	85	0.527	1.364	0.107	0.289	0.083
Time	85	7.118	19	0	4.536	0.493
Size	85	22.119	23.975	20.63	0.951	0.904
Reward	85	5.858	8.488	85	1.045	1.092

Table 107.5 Regression results of equity incentive on dividend policy in material industry

Variable name	Dpr		Variable name
	Model 1	Model 2	
eso1	0.0967**	0.282**	eso2
	−2.03	−2.51	
Roe	0.242***	0.194***	Roe
	−3.64	−3.25	
Capacity	0.059	0.150*	Capacity
	−0.62	−1.83	
Time	−0.024***	−0.028***	Time
	(−2.83)	(−3.29)	
Size	0.106**	0.139***	Size
	−2.6	−3.55	
Reward	−0.011**	0.005	Reward
	(−0.58)	−0.22	
Eas	−0.024	0.048	Eas
	−0.13	−0.3	
−cons	−1.924**	−2.783***	−cons
	(−2.19)	(−3.37)	

Note ***indicates that the figure is significant at the 1 % level
**indicates significant at the 5 % level
*indicates significant at the 10 % level

Table 107.6 Regression of impact of equity incentive on dividend policy in seven industries

Industry	Capital goods	Software and service	Real estate	Drug, biotech-nology and bioscience	Consumer durable clothing	Drug, biotech-nology and bioscience	Material II
eso1	−0.067***	−0.105***	−0.07***	0.021	−0.233**	0.171***	0.0967**
	(−3.94)	(−584.39)	(−8.56)	−0.43	(−2.6)	−2.98	−2.03
eso2	0.023	−0.330***	−0.078***	−0.086*	−0.856*	0.233***	0.282**
	−0.65	(−3.71)	(−16.08)	(−1.84)	(−1.84)	−3	−2.51

Note ***indicates that the figure is significant at the 1 % level
**indicates significant at the 5 % level
*indicates significant at the 10 % level

level of incentive also presents a positive correlation with dividend payout ratio. In these two models, roe, listed time and company size all have a positive correlation with dividend payout ratio, which is consistent with the theory–companies are more inclined to pay cash dividend if they have long listed time, stable operation and considerable profit (Table 107.6).

Now we look throughout the regression results of the whole 7 industries. It is clear that the companies which carried out equity incentives in capital goods, software and service, real estate and consumer durables and clothing industries, remarkably tend to reduce cash dividend. And in these four industries, except for capital goods, the degree of equity incentive is significantly negative-correlated with the dividend payout ratio in other three industries.

However, in the remaining three industries, both two variables have positive correlation with dividend policy in technology and hardware industry and material industry. Additionally, the two equity-incentive variables show different correlations with dividend payout ratios, but there are insignificant parts in each correlation. In this way the results partly verified our Hypothesis 1 and Hypothesis 2.

The study results above are generally consistent with the industrial features. For example, capital goods is an industry which realizes its value-added process and improves efficiency by making good use of capital market regulations and technically running the capitals. Companies attached to this industry need a large amount of money to support their normal operation. It can be inferred that the management is unwilling to pay cash dividend after weighing its benefit even though the equity incentives are carried out. Software and service industry needs continuous reinvestment to research and develop new software, and real estate industry also faces lots of reinvesting opportunities in terms of urban constructing and planning. Therefore it is reasonable that these industries have a negative correlation between study variables.

On the contrary, technology and hardware industry and material industry are traditional industries which have relatively stable capital input and operation. The animated management has the motive to increase the dividend payout ratio under Chinese dividend policies background, because not only can they obtain the cash dividend but also avoid share impairment from investing failure. Besides, many listed companies in traditional industries have developed to the mature stage and therefore have motivation to return to their shareholders. The positive correlation result of these industries also meets their industrial characters.

The management in high-growth industries is often aspired to take effective strategies such as reinvestment in order to meet the vesting conditions, but both over-investment and investment failure may harm the company and shareholders interest. So the listed companies in high-growth industries should set an effective incentive level to avoid that the dividend payout ratio is too low or discontinuous from management's over-investment and other self-serving behaviors. On the other side, listed companies in mature and stable industries could prompt their cash dividend through improving equity incentives in term of their own needs.

107.4.5 Further Empirical Results and Analysis Under Different Level of Management Power

The inference that the management may take advantages of individual power to seek for their personal gains is based on the defect in Chinese corporate governance system that the chairman and CEO is the same person. So we assess the management's power by whether there is such policy in the company. If so, we put it into Major Power of Management; if not, we put it into Minor Power of Management. As the sample

Table 107.7 Comparative study under different level of management power in material industry

Model	Model 1		Model 2	
	Major management authority	Minor management authority	Major management authority	Minor management authority
eso1	0.0502	0.109**	–	–
	−0.71	−2.51	–	–
eso2	–	–	−0.077	0.345***
	–	–	(−0.27)	−3.01
Roe	0.457	0.347***	0.689	0.084
	−0.48	−4.3	−0.88	−1.01
Size	0.051	0.108***	0.091	0.135***
	−0.42	−2.84	−0.81	−4.52
Reward	0.130*	−0.026	0.163**	0.018
	−1.86	−1.24	−2.54	−1.03
Eas	−0.208	−0.269	−0.303	0.085
	(−0.61)	(−1.12)	(−1.08)	−0.45
Time	−1.467	C0.041***	−0.0699	C0.029***
	(−0.51)	(−3.46)	(−1.44)	(−2.62)

Note ***indicates that the figure is significant at the 1 % level
**indicates significant at the 5 % level
*indicates significant at the 10 % level

shrunk after classifying the management's power, the regression results from limited samples could not describe the whole industries effectively. So we only did research on material industry and software and service industry in the fourth part.

We can see from Table 107.7, for both Model 1 and Model 2, the impact of equity incentive on dividend payout ratio under major management power is less significant than that under minor management power, which verified our Hypothesis 3. In Table 107.8, the results of software and service industry in Model 1 also verified Hypothesis 3: if the management has too much power, the correlation between equity incentive and dividend policy will be weakened.

If the management has unfettered power, it is more likely for them to manipulate share price through speculative behaviors such as controlling granting time of equity incentive plan and publishing time of 'good news', and they would have bigger controlling power on dividend policy. The equity incentive plan was designated to alleviate the interest conflicts between shareholders and the management, and it has binding effect on dividend policies. But when this management mechanism is mingled with speculative factors, the binding effect is consequently weakened. In conclusion, listed companies should consider their own industrial characteristics and managerial power structure while setting the incentive plans to ensure company's effectiveness and shareholders' interests.

Table 107.8 Comparative study under different level of management power in software and service industry

Model	Model 1		Model 2	
	Major management authority	Minor management authority	Major management authority	Minor management authority
eso1	−0.1	−0.154*	–	–
	–	–	–	–
	(−0.42)	(−2.04)	–	–
eso2	–	–	−8.994	0.03
	–	–	(−1.6)	(−0.17)
Roe	−0.912	1.150***	0.985**	1.807***
	(−0.19)	(−2.07)	(−2.62)	(−4.86)
Size	0.12	−0.006	0.123**	0.147***
	(−0.36)	(−0.14)	(−2.31)	(−2.23)
Reward	−0.045	0.036	C0.044***	C0.063*
	(−0.02)	(−0.49)	(−3.24)	(−1.91)
Eas	−0.023	0.245	−0.129	−0.211
	(−0.01)	(−0.86)	(−0.60)	(−1.32)
Time	0.297	0.036**	0.022	*C*0.002
	(−0.14)	(−2.58)	(−0.71)	(−0.17)

Note ***indicates that the figure is significant at the 1 % level
**indicates significant at the 5 % level
*indicates significant at the 10 % level

107.5 Conclusions and Suggestions

The purpose of this article is to study the impact of equity incentives on dividend policies in different industries. Meanwhile, we classified the management power from the point of behavior subjects in the empirical process. After synthesizing the present policy background, theoretical analysis and empirical research results, we reached the following conclusions:

1. At present, Chinese listed companies that conduct equity incentives on the management centralize in well-developed industries. The research samples we selected were industries with more animated companies, many of which that have higher level of incentives are high-growth industries, such as software and service, technology and hardware, and drug, biotechnology and bioscience. The size of external directors in high-growth industries is usually smaller than that of traditional industries. Yet the main role of external directors is to over see the BOD and the management, which may overlap the effect of equity incentive mechanism to a certain degree. So high-growth industries are more generous in paying cash dividend.
2. The equity incentive and the dividend payout ratio show a significant correlation, but the direction of correlation varies among industries. In general, high-growth industries have a negative correlation while the traditional industries have a

positive one. Through further study we found that the industries with a negative correlation, their roe ratio, company size are also negatively correlated with dividend payout ratio. We can see that in high-growth industries such as software and service, they use equity incentive policy to mitigate risk and agency problem to better govern the corporation. As their net profit increases and company scale expands, they become more unwilling to pay cash dividend yet. These listed companies have great potential in the future, and their objective of going public is to raise fund and expand rapidly. The capital market should give a hand to these industries rather than put much emphasis on paying cash dividend. In contrast, the companies in traditional industries such as material industry have come into mature and stable stage in the capital market. It is capable for them to seek for shareholders return and therefore their willingness to pay cash dividend is stronger and their spending on this is greater.

3. The variable of whether a company implements equity incentives and the variable of the degree of equity incentives have the same effect direction on dividend policies, which means that both variables have a positive impact on dividend payout ratio.
4. Unfettered power of management can weaken the correlation between equity incentives and dividend policies. For listed companies that have a weak scrutinizing and balancing mechanism, they lack a constraint on management authority and thus providing convenience for management to make use of their power to manipulate the corporate decision-making process. Besides, as the effect of equity incentives on dividend policies is different among industries, Chinese listed companies should consider industrial characteristics and their impact on dividend policies when setting equity incentive plans. Chinese listed companies should also conduct equity incentives based on their own conditions and prevent the dividend payout ratio being too low to harm minority shareholders'interests or over-investment behaviors damaging the corporate value. Furthermore, it is quite important for Chinese listed companies to make good use of the positive effect of equity incentives on cash dividend based on industrial characteristics. They should try to make equity incentives be effectively exerted, to pay back shareholders and improve corporate performance, and to make the company develop healthily.

Since the equity inventive policy started quite late in China, we could not collect sufficient samples. We only took a part of industries as representatives while verifying the correlation between equity incentive and dividend policy, and when we took the power of management into account, this was also the case. In addition to that, we only considered whether the chairman and the senior management is a same person of the company when assessing the power of management, and also ignored other factors such as ownership concentration. These defects restrict the practical applications to some extent.

Acknowledgments The authors would like to acknowledge the financial support from the National Science and Technology Support Programme Project (2012BAH31F01), the Soft Science Project of Sichuan Province (2008ZR0140) and the Science and Technology Infrastructure Platform Project of Sichuan Province (2015JCPT0006).

References

1. Aboody D, Kasznik R (2000) CEO stock option awards and the timing of corporate voluntary disclosures. J Account Econ 29(1):73–100
2. Bi F (2014) Power management, equity incentive and dividend policy. Master's thesis, Southwest University of Finance and Economics
3. Guo H (2013) The impact of management authority acts on dividends of listed companies-evidence of a-share listed companies based. Zhongnan Univ Polit Sci Law 01:137–143
4. Hang HB, Lv CJ, Li R (2012) Inefficient pricing, management equity incentive and stock dividend. J Account Econ 47–56
5. Hu GQ, Zhang JM (2013) Protective equity incentive cash dividend policy–evidence from chinese listed companies. Econ Manag Res 18–26
6. Liljeblom E, Pasternack D (2006) Share repurchases, dividends and executive options: the effect of dividend protection. Eur Financ Manag 12(1):7–28
7. Luo FB, Ran MS, Du JT (2013) Empirical research about executives equity incentive and investment decisions relations. Account Res 08:69–76
8. Lv CJ, Zhang HP (2012) Listed companies incentive plan on the dividend distribution policy. Manag World 11:133–134
9. Mehran H (1995) Executive compensation structure, ownership, and firm performance. J Financ Econ 38(2):163–184
10. Wu YH, Wu SN (2010) Executive compensation: incentive or self-interest?-Evidence from Chinese listed companies. Account Res 11:40–48
11. Xiao SF, Yu MY (2012) Equity incentive and dividend-evidence from listed companies in China. Account Res 08:49–57
12. Xu D (2014) Equity incentive, empirical research dividend and insider manipulation. Master's thesis, Inner Mongolia University of Finance and Economics
13. Ye JY, Zhang DL (2014) Equity incentive, empirical research dividend and insider manipulation. Financ Econ Issues Res 02:60–66
14. Zhang DL, Ruan AP (2013) Correlation of equity incentive and restraint mechanism and performance-empirical evidence from Chinese listed companies. Financ Econ Issues Res 01:3–12
15. Zhou JB, Sun JS (2003) Research governance effect of equity incentive operator—evidence from listed companies in China. Econ Res 05:74–82

Chapter 108
Influential Factors Mining on the Development of Classification System of Diagnosis and Treatment

Li Luo, Yuanhang Zheng and Ruihong Shu

Abstract The Classification system of diagnosis and treatment, which was first introduced in 2014 in China, now is rapidly becoming a hot issue in China. Many scholars analyzed this policy from current situation, lacking in scientific and systematic approaches to analyze and separate influencing factors of current development. In this paper, we apply the Interpretation Structure Model (ISM) to analyze the result from the relationship among factors which are divided into two classes: patient and hospital, based on 8000 data of patients from investigation and survey in hospitals at various three levels in Sichuan Province. We divide the factors into five influential levels. The direct reasons are the "Policy recognition degree" and the "Recommended by others", and the root cause is the "Serious condition of the disease". We also put forward suggestions for the development of the Classification System of Diagnosis and Treatment, for instance, the small hospitals should establish the complete index systems including medical equipment, the number of doctors and the kinds of diseases which can be diagnosed, and the demonstrations of the information such as resources in this small hospital. So we can solve the problems under the conditions of limited resources, step by step, based on the primary or secondary factors.

Keywords Classification system of diagnosis and treatment · Systems engineering · Interpretation structure model

---

L. Luo · Y. Zheng (✉)
Business School, Sichuan University, Chengdu 610064,
People's Republic of China
e-mail: 464049245@qq.com

R. Shu
School of Energy and Power Engineering, NUST, Nanjing 210094,
People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_108

108.1 Introduction

The Classification system of diagnosis and treatment, which was first introduced in 2014 in China, now is rapidly becoming a hot issue in China. The core connotation of this system is that “If suffer from a serious illness please go to the tertiary and large general hospitals, but if suffer from an unserious illness please go to small hospitals. For the first diagnosis, please go to the primary hospitals, and implement two-way referral system”.

Currently, there are many scholars analyzing this policy by describing the current situation. Liang [7] studied the experience of classification system of diagnosis and treatment in Taiwan. The implementation of this system in Taiwan mainly reflected in the difference of “basic budget of outpatient” in general hospitals. Referrals pay less money than the patients coming directly. However, the burden of drugs and burden of hospitalization are not differentiated by referral or not. Zhu and Wu [18] studied the system through distributing questionnaires and researching the problems in current situation in Liaoning Province. They found that many patients spontaneously go to the general hospitals from primary hospitals due to the ineffectual treatment, while the two-way referral relationships between medical institutions at various levels have not been universally established. Yang et al. [14] studied the medical personnel’s cognitive on the classification system of diagnosis and treatment. Sun [11] studied the problems of primary level medical institutions in Yuecheng district, Shaoxing city under the classification system of diagnosis and treatment.

What’s more, there are other scholars using statistical methods to study different influential factors of choosing hospitals in patients. Some scholars analyzed the factors from the angles of family and patient. Puts et al. [9] studied the factors influencing older adults’ decision to accept or decline cancer treatment. Important factors for accepting treatment were convenience and success rate of treatment, seeing necessity of treatment, trust in the physician and following the physician’s recommendation. Xiong [13] studied the effect of travel time on outpatients’ choices for hospital. Kalda et al. [5] also studied the influential factor such as patient satisfaction with care. Their overall satisfaction with the physician as well as satisfaction with several aspects of primary health care was significantly higher compared with those of unregistered respondents. Qin [10] studied the patient’s choice in health seeking through an example of Tianjin. The others analyzed the factors from the angles of hospital and medical insurance. For example, Paternotte et al. [8] studied the Factors influencing intercultural doctor-patient communication. The effect of doctor-patient communication mostly influences the patients’ choices for hospital. Yassini et al. [16] studied the most important factors influencing physician choice from the doctor. Their results of questionnaire survey show that the factors include doctor’s spending enough time for examination and being particularly interested in the patients’ problems. All of these articles use statistical methods to study this problem, not yet from the perspective of System angle to consider. However, the classification system of diagnosis and treatment is a complex project.

In this study, we designed questionnaires through referring papers and then interviewed three hundred of patients in the three levels of hospitals in Chengdu city, Sichuan province. Then we applied one of the methods of system called "Interpretive structural modeling (ISM)" to analyze the influential factors of the development of classification system of diagnosis and treatment. As a result, we divided the factors into direct, indirect and root cause. Finally, based on the result of the model, we put forward some recommendations for promoting the development of the system.

The rest of the paper is organized as follows. Section 108.2 presents the basic theory of ISM model. Section 108.3 presents the process of factors' selection and determination in questionnaire and the design of questionnaire. Section 108.4 resents the process of constructing ISM model of factors affecting the development of Classification system of diagnosis and treatment in details. Section 108.5 gets the results and the Sect. 108.6 gives the conclusions and recommendations for promoting the development of the system.

108.2 Basic Theory of ISM Model

Interpretive structural modeling (ISM) is developed by Professor Warfield in the United States in 1973, mainly for analysis of complex socio-economic systems of international problems such as structural problems from energy resources to the problem of traffic accidents, such as the scope of regional development, personal and enterprise-wide problems, which almost use this model.

Basic thought of ISM is: extract constitute elements of problems through some creative technology, using directed graph, matrix tools and computer technology, processing on elements and mutual relationship these information and then last with text, explaining and description. Finally, clear level and overall structure of the problem, so as to improve the awareness of the problem. Step of Analysis for problems as follows: ① Organize a group for implementation ISM; ② set the key problem and select out the system elements; ③ study for the interrelationship between the various elements in order to establish an adjacency matrix and reachability matrix; ④ decompose reachability matrix, and model the structure for this problem; ⑤ establish interpretive structural model based on the structural model. At last, analyze for it.

108.3 Selection of Factors and Questionnaire Designing

The development of classified diagnosis and treatment is a Systems engineering, which is definitely affected and restricted by various factors. In order to investigate the factors that influence the development of the system, and also be easy to make a questionnaire, we have access to a large number of relevant literatures about how to design a good questionnaire and medical needs.

After reading, we extract the following factors and reasons for choosing them to design questionnaires.

(1) Acceptance of the highest level of Education

The acceptance of the highest level of education largely influences Family income by reading the literature, and the education may influence the cognition and acceptance of policy or some new things. So this factor is much important.

(2) Family monthly income

We know the average family monthly income in Sichuan province is 3808 RMB by referring to the latest statistical yearbook called "Sichuan province human resources and social security enterprise development statistical bulletin in 2014". We also know that different income greatly influences the one's choice when he is ill. So we divide the family monthly income into six categories in our questionnaire. (Six categories are "below 2800","2800–5000", "5000–6700", "6700–9300", "9300–10000", "10000 above". All the unit of money is "RMB").

(3) Live in residence

In China, for one thing, there is a great difference between urban medical insurance and rural cooperative medical system. For another, where you live will affect the type of medical insurance. If you're a residency, you have the medical insurance for urban residents. However, if you live in the countryside, you can only have cooperative medical insurance in rural areas.

(4) Medical reimbursement way

There are some differences between social security for urban residents and social security for rural residents. Susan [15] studied the relationship between patients and doctors. Results are that the doctors are important for in the relationship. Yin [1] concluded that "pension insurance coverage in countryside in China was only 10.2 % in the year of 2009, only 25 % of the urban coverage. Moreover, seen from the level of per security, pension insurance for urban residents was about 12.6 times the pension insurance for rural residents". Although institution of the New Rural Cooperative Medical Care have implemented, there are many differences between urban residents and rural residents.

(5) Distance from home

Distance from hospital to home largely affects the patients' choice of hospital. Li et al. [6] pointed that hospitalized demands for rural patients are significantly affected by hospital distance from home. The probability that patients go to the hospital for treatment will decrease with the increased distance to hospital, and it is changed among different levels of hospital: the more primary hospitals there are, the greater it impacts.

(6) Serious condition of the illness

There are many studies show that the condition of the illness can largely influence the patients' choices. Statistics show that when patients are seriously ill, general hospitals and municipal hospitals are patients' preferred choices followed by major hospitals, community hospitals, dispensaries, and finally the individual clinics. It also shows that most choices of patients for the medical treatment are rational for serious condition of the illness [10].

(7) Policy awareness

Creating classification system of diagnosis and treatment, not only is an important initiative to rationally allocate medical resources and promote equal access to basic health services, but also a major part of medical and health system with Chinese characteristics. It is of significance to promote the long-term medical and health development and enhance people's health and the quality [3].

(8) Policy recognition degree

Awareness of medical policy influence on the recognition of policy and recognition also greatly affect patients' choices of hospital. There was a survey in Kunming City, concluding that when patients were aware of medical policy they were more likely to accept the policy and then implement it [19].

(9) Doctor's medical skill

Patients mainly consider medical technology when they decide to choose doctors and most patients tend to choose experts. Wei [12] surveyed and concluded that patients were more likely to choose experts with high technical level, rich clinical experience and high professional quality.

(10) Hospital popularity

"Practice is the sole criterion for testing truth" and we often believe what public consider, so we are willing to go to the popular hospitals and the hospital which is recommended by others if we are ill. Zhao [17] studied and found that if patients were not familiar with hospital, they will go to the popular and famous hospital.

(11) Medical equipment

There are large differences between large the general hospitals and the small community hospitals in medical equipment. Zhu et al. [18] surveyed and studied the present situation of health resource allocation and utilization in Nanjing. Only 17.1 % number of beds in this city distribute in community health service centers and rural township. Moreover, the total possession of the tertiary and large general hospital is 9 times that of primary hospital.

(12) Service attitude of doctors and nurses

Not only effect of curative influences the choice of patients, but also the service attitude of doctors and nurses will make some difference. Dai et al. [2] studied and surveyed the relationship between patients and doctors. The Conclusion of the study is "Problems in the process of treatment most due to miscommunication and lack of trust".

(13) Cost

Many patients play the game between "disease can be cured" and "cost" for the choice, in which costs as a key factor are in restricting the choices of many patients. The choice is related to doctors' medical skills, convenience of treatment and the cost [12].

(14) Condition of the disease recovery

If a patient recovers well after treatment in a hospital, he will go there next time. It is easily to cultivate patient's loyalty like in business.

(15) Recommended by others

Hu [4] studied the relationship between patients' satisfaction and oral spreading and found that patients with different degree of satisfaction will make different public effects. Patients with high degree of satisfaction will recommend the hospital for others. However, if patients were not satisfied they didn't want to come in once more even issued calls to boycott.

After choosing the above influential factors, we made the questionnaire and investigated for the study of influential factors mining on the development of classification system of diagnosis and treatment. In the next section, we give the process of analysis and modeling based on the ISM method.

108.4 Construct ISM Model of Factors

108.4.1 Full Structure Analysis and Select the Key Factors

Since the most significant performance hindering the development of graded clinics is: a lot of people after the illness diagnosed go to a large General Hospital directly, not to a grass-roots hospital, contravening the provisions of the classified diagnosis and treatment policies. West China Hospital of Sichuan University represents China's second-largest General Hospital, based on geographical restrictions of research, so we put "first diagnosis is in West China Hospital of Sichuan University" as a factor of in analysis.

In this paper, using significance analysis in SPSS, we select and assure 15 major and typical influence factors in this system from patient and hospital these two aspects (indicated with $S_1, S_2, S_3, \ldots, S_{15}$), and the extinct contents as follows.

Family monthly income (S_1), Acceptance of the highest level of Education (S_2), Live in residence (S_3), Medical reimbursement way (S_4), Serious condition of the illness (S_5), Policy awareness (S_6), Policy recognition degree (S_7), Doctor's medical skill (S_8), Hospital popularity (S_9), Medical equipment (S_{10}), Distance from home (S_{11}), Cost (S_{12}), Condition of the disease recovery (S_{13}), Recommended by others (S_{14}), first diagnosis is in West China Hospital of Sichuan University (S_{15}).

108.4.2 Construction of ISM Model of Factors Affecting the Development of the Classified Diagnosis and Treatment

Based on the above analysis, we can see that only considering the aspects of patients and hospitals, there are many factors restricting implementation of classification system of diagnosis and treatment. For this reason, it is of necessity to analyze the above typical factors influencing the development of the system. But different from previous research, this article is not list the factors easily but use the interpretive structural modeling (ISM) which is one of the methods in Systematic engineering, and then constructs the model of influencing factors and divide the factors level.

Provide appropriate recommendations for the development of classified diagnosis and treatment so as to promote the reform of medical system and the implementation of a national medical policy.

This section will analysis these typical factors above influencing the development of classified diagnosis and treatment step by step, according to the ISM model, to construct the ISM model of factors affecting the development of classification system of diagnosis and treatment.

(1) Analyze the relationships between factors

We analyze the relationships among these fifteen factors through the method of "Experts discussion" (or "Delphi" method) based on the results of valid questionnaires. Then we summary mutual relations among them and represent it in a directed graph.

The relations between "development of classified diagnosis and treatment" and affecting factors below are listed in Table 108.1.

(2) Establish the adjacency matrix

Adjacency matrix represents direct relations between the various elements of the system. Definition of adjacency matrix A as follows:

$$A = [a_{ij}]_{n\times n},$$
$$a_{ij} = \begin{cases} 1, \ S_i R S_j (\text{“}R\text{” represent that } S_i \text{ have influence on } S_j), \\ 0, \ S_i f S_j (\text{“}f\text{” represent that } S_i \text{ havn't influence on } S_j). \end{cases}$$

Table 108.1 Analysis table of the factors

Impact factor	Influenced factors
Family monthly income (S_1)	S_{12}, S_{15}
Acceptance of the highest level of Education (S_2)	S_1, S_6, S_7
Live in residence (S_3)	S_4, S_{11}
Medical reimbursement way (S_4)	S_{12}
Serious condition of the illness (S_5)	S_8, S_{11}, S_{12}, S_{13}, S_{15}
Policy awareness (S_6)	S_7
Policy recognition degree (S_7)	S_{18}
Doctor's medical skill (S_8)	S_9, S_{13}, S_{14}, S_{15}
Hospital popularity (S_9)	S_{12}, S_{15}
Medical equipment (S_{10})	S_9, S_{12}, S_{14}, S_{15}
Distance from home (S_{11})	S_{12}, S_{15}
Cost (S_{12})	S_{13}, S_{15}
Condition of the disease recovery (S_{13})	S_{14}
Recommended by others (S_{14})	S_{15}
First diagnosis is West China Hospital of Sichuan University (S_{15})	

Table 108.2 Adjacency matrix 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
2	1	–	–	–	–	1	1	–	–	–	–	–	–	–	–
3	–	–	–	1	–	–	–	–	–	–	1	–	–	–	–
4	–	–	–	–	–	–	–	–	–	–	–	1	–	–	–
5	–	–	–	–	–	–	–	1	–	–	1	1	1	–	1
6	–	–	–	–	–	–	1	–	–	–	–	–	–	–	–
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
8	–	–	–	–	–	–	–	–	1	–	–	–	1	1	1
9	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
10	–	–	–	–	–	–	–	–	1	–	–	1	–	1	1
11	–	–	–	–	–	–	–	–	–	–	–	1	–	–	1
12	–	–	–	–	–	–	–	–	–	–	–	–	1	–	1
13	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Establish an adjacency matrix based on the analysis table. Matrix 1 as follows in Table 108.2.

(3) Establish reachability matrix "R"

Reachability matrix describes the connection between nodes (factors), after a certain length of pathway can reach the level that indicates the direct and indirect structural relationships among various elements. For a system "S", we define the reachability matrix "R" as follows:

$$R = [r_{ij}]_{n*n},$$
$$r_{ij} = \begin{cases} 1, & S_i R S_j (\text{“}R\text{” represent that } S_i \text{ can reach } S_j, \\ 0, & S_i f S_j (\text{“}f\text{” represent that } S_i \text{ can't reach } S_j. \end{cases}$$

and $r_{ii} = 1$ (means every nodes can reach themselves).

Adjacency matrix A together with the identity matrix I, followed by rules of Boolean algebra is multiplied by itself, until a power equal to the product of all, and this product is equal to the center of the reachability matrix. The formula is as follows:

$$(A + I) \neq (A + I)^2 \neq \cdots \neq (A + I)^k = (A + I)^{k+1} (k \leq n - 1),$$

so

$$R = (A + I)^k.$$

Table 108.3 Reachability matrix 2

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	–	–	–	–	–	–	–	–	–	–	1	1	–	1
2	1	1	–	–	–	1	1	–	–	–	–	1	–	–	1
3	–	–	1	1	–	–	–	–	–	–	1	1	–	–	1
4	–	–	–	1	–	–	–	–	–	–	–	1	1	–	1
5	–	–	–	–	1	–	–	1	1	–	1	1	1	1	1
6	–	–	–	–	–	1	1	–	–	–	–	–	–	–	1
7	–	–	–	–	–	–	1	–	–	–	–	–	–	–	1
8	–	–	–	–	–	–	–	1	1	–	–	1	1	1	1
9	–	–	–	–	–	–	–	–	1	–	–	1	1	–	1
10	–	–	–	–	–	–	–	–	1	1	–	1	1	1	1
11	–	–	–	–	–	–	–	–	–	–	1	1	1	–	1
12	–	–	–	–	–	–	–	–	–	–	–	1	1	1	1
13	–	–	–	–	–	–	–	–	–	–	–	–	1	1	1
14	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1

The paper got the reachability matrix “R” based on the adjacency matrix using the ISM software for calculation. See Matrix 2 in Table 108.3.

(4) Establish reduced matrix “T”

(5) Divided factors into hierarchical levels

If use the “L_1”, “L_2” ,…, “L_k” ($k \le n$) to indicate all levels from top to bottom, the level of system “S” is available to the following formula:

$$L(S) = (L_1, L_2, \ldots, L_k).$$

Using the ISM software, we get the specific classification shown as follows:

$L_1 = \{S_{15}\}$; $L_2 = \{S_7, S_{14}\}$; $L_3 = \{S_6, S_{13}\}$; $L_4 = \{S_{12}\}$; $L_5 = \{S_1, S_4, S_9, S_{11}\}$; $L_6 = \{S_2, S_3, S_8, S_{10}\}$; $L_7 = \{S_5\}$.

(6) Establish the interpretative structural model

According to the grades of the above elements, draw the relationship between adjacent levels to model the structure, which is shown in Fig. 108.1.

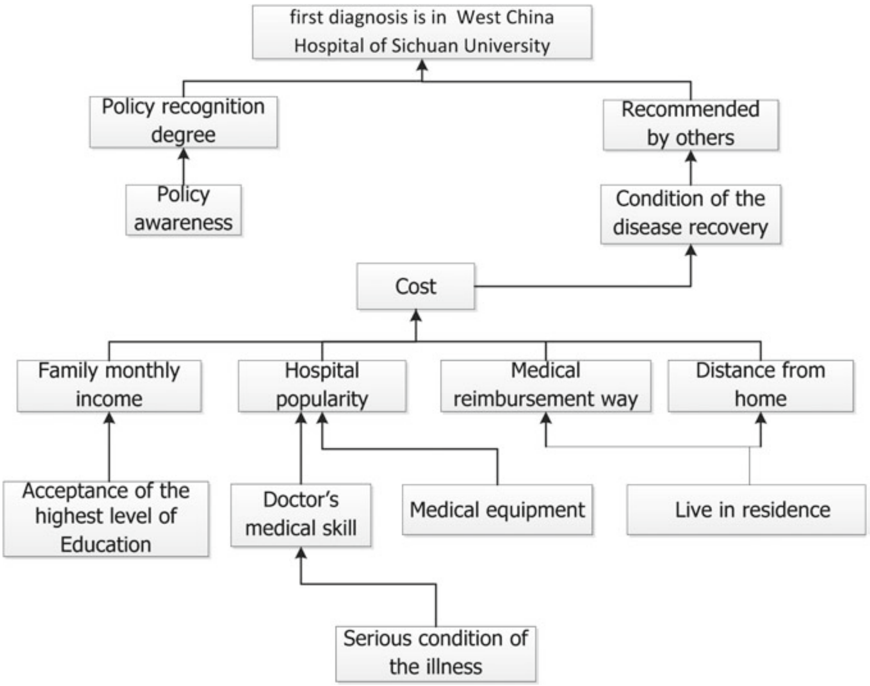


Fig. 108.1 The interpretative structural model for the classification system of diagnosis and treatment

108.5 Results

According to the model, we can see the factors that directly cause patients' choices of "first diagnosis is in West China Hospital of Sichuan University" are "Policy recognition degree", "Recommended by others", "Policy awareness", "condition of the disease recovery". By talking with patients in some small hospitals, we know that if they are aware of the policy and indeed identified with it, they may not choose to go to the tertiary and large general hospital. However, when others especially friends or relatives recommend West China Hospital of Sichuan University for them, they are willing to go there at first choice. We can also see that people's awareness of policy affect their recognition of policy sometimes. So if we can improve the recognition of policy in public, it will make effect on the development of classification system of diagnosis and treatment.

The indirect factors are the "Cost", "Family monthly income", "Hospital popularity", "Hospital popularity", "Medical reimbursement way", "Distance from home" of hospitals. Followed by are the factors of "Acceptance of the highest level of education", "Doctors' medical skills", "Live in residence", "Medical equipment". Cost influences the patients' choices much, and when people don't have enough money they can only go to the small hospitals. And through interviewing a doctor of a small hospital, we learned that patients pay much attention to the medical equipment of hospital, including the equipments for checking and equipment for treatment. If the hospital does not have corresponding equipment for check or patients don't know what equipment the hospital has, which would cause that patients do not trust in primary hospitals or community clinic. The result is that patients' first diagnosis is tertiary and large general hospitals once they get ill. After all, equipment in larger general hospital is more advanced, better for check and treatment. What is worthwhile is that "Doctor's medical skill" is not the direct reason. Obviously, in today's society patients are more willing to believe in equipment rather than fully trust the doctors, perhaps there is few "Look, smell, ask and diagnose" doctors.

What is worthy to note is that the root reason is "Serious condition of the disease". Everyone only lives once. If the disease is indeed serious, they pay more attention to the treatment effect rather than the cost.

We can be informed through the following figure that: "Medical equipment" can affect "Hospital popularity" as well as "Condition of the disease recovery" can affect "Recommended by others". We can see that it is essential for hospitals to have some high-tech equipment. Because patients want to go to the hospital for once which can accurately determine the cause. Moreover, when patients recover from the illness soon or they are better after the treatment, they are willing to recommend the hospital to their friends and relatives. And that's why the effect of reputation is important for hospitals.

108.6 Conclusion and Recommendation

(1) Strengthen the Construction of Information

Strengthen the construction of information technology and provide technical support for the classification of diagnosis and treatment. Accelerate the construction of provincial, city and county three health information platform. Establish standard medical information system concluding electronic health records and electronic medical records. Break the barriers between medical institutions at all levels. Implement inspection information and the patient in the treatment process of sharing, and establish the reunification of the province's appointment, medical consultation and health education platform.

(2) Improve Primary Hospitals' Level of Business

For basic-level hospitals, in the continuous improvement of the level of medical equipment and reduce drug purchase profit, to improve the medical staff requirements. So that patients with a full range of multi-level trust that they can be implemented in the primary hospital. On the other hand, staffs in primary hospital should go to the community or the town to do some advocacy about hospital's medical standards and national health policy.

(3) Establish A Complete Medical Instrument, Medical Human Resources and the Index System of Disease

In the interviews, we found that a few patients are in many community hospitals, where the huge cost of buying expensive equipment. So it makes a very long time to get the cost back. Although the country has financial and human support efforts, people do not know what equipment the community hospital has and what kind of disease it can cure, so the hospital can't get the recognition and trust of people. Therefore, the hospitals are unwilling to buy large medical equipment. Then people will not be willing to go to the community hospital to see a doctor. Such a vicious circle, results in a large number of idle resources in community clinics and large hospitals are overcrowded causing the phenomenon "difficult for medical treatment". This is an important reason that the resource allocation and utilization of rate is quite unbalanced.

(4) Strengthen Exchanges In Various Aspects and Promote The Development of Health Care Reform

The implementation of hierarchical diagnosis and treatment of the patients in the treatment processes offer certain preferential treatment. At the same time, the large hospital can regularly held medicine discussion with local primary hospital to offer the primary hospital hardware and software support, and the large hospital can achieve common channels of information with the primary hospitals, strengthen the construction of information, even become hierarchical promoters on the implementation of the medical treatment.

Acknowledgments This study is sponsored by the Nature Science Foundation of China (71532007, 71131006, 71172197) and Central University Fund of Sichuan University Number skgt201202. Here we acknowledge the support from West China Hospital of Sichuan University.

References

1. Barone SM, Lazzaro-Salazar M (2015) 'Forty bucks is forty bucks': an analysis of a medical doctor's professional identity. Lang Commun 43:27–34
2. Dai Y (2012) Current situation, problems and reasons of doctor-patient relationship in China: an empirical analysis based on the perspective of health communication. Journal Rev 4:15–20 (in Chinese)
3. General Office of the State Council of China (2015) Guiding opinions of the general office of the state council on promoting the construction of the classified system of diagnosis and treatment (in Chinese)
4. Hu L (2008) An empirical study on the relationship between patient satisfaction and oral spreading in modern hospital. Ph.D. thesis, Medical University in Hebei Province (in Chinese)
5. Kalda R, Põlluste K, Lember M (2003) Patient satisfaction with care is associated with personal choice of physician. Health Policy 64(1):55–62
6. Li L, Wang J, Yuan J (2014) The influence of hospital distance on the demand of residents in rural areas: application of a discrete choice model. Chin Health Econ 1:11–13 (in Chinese)
7. Liang J (2015) Experience and reference of the classified diagnosis and treatment system in taiwan area. PhD thesis, Social security in China (3):82–83 (in Chinese)

8. Paternotte E, van Dulmen S, van der Lee N, Scherpbier AJ, Scheele F (2015) Factors influencing intercultural doctor-patient communication: a realist review. Patient Educ Couns 98(4):420–445
9. Puts MT, Tapscott B et al (2015) A systematic review of factors influencing older adults' decision to accept or decline cancer treatment. Cancer Treat Rev 41(2):197–215
10. Qin Y (2011) An empirical study on the patient selection - taking tianjin area as an example. Bus Econ 10:93–96 (in Chinese)
11. Sun M (2015) Problems and countermeasures of primary medical institutions in the classification of medical institutions in Shao Xing City. Chin Community Dr 31(17):157–159 (in Chinese)
12. Wei M (2013) Analysis on influencing factors of patients' choice of hospital. Ph.D. thesis, Medical University of Anhui (in Chinese)
13. Xiong J, Xia X et al (2012) Study on the influence of bus travel time on the choice of outpatients for hospital. Clin J Pract Hosp 9(3):188–190 (in Chinese)
14. Yang Y (2015) Cognition and influencing factors of medical and health personnel grading diagnosis and treatment mode in Guangzhou city. Chin Health Manag 1:22–26 (in Chinese)
15. Yassini S, Harrazi M, Askari J (2010) The study of most important factors influencing physician choice. Procedia-Soc Behav Sci 5:1945–1949
16. Yin H (2011) Research about impact of social security to China's rural consumer behavior. Ph.D. thesis, Southwestern University of Finance and Economics (in Chinese)
17. Zhao L (2008) A study on the behavior of consumers in the choice of hospital in medical service. Ph.D. thesis, Central China University of Science and Technology (in Chinese)
18. Zhu M, Wu H (2015) Thoughts on the construction of classified diagnosis and treatment system in Liaoning Province. Soc Secur China 3:79–81 (in Chinese)
19. Zhuang Y (2013) Analysis on influencing factors of awareness rate and willingness of two way referral in outpatients. Ph.D. thesis, Medical University in Kunming (in Chinese)

Chapter 109
The Impact of Family Background on Individual's Temporary Employment Choice: A Chain Mediation Model

Xiaoye Qian, Xianli Zheng and Hao Zhou

Abstract In this study, we try to answer an important question of how disadvantages of family background diminish a worker's ability to obtain regular employment. Using the intergenerational mobility theory, we propose a chain mediation model to show how family background impacts an individual's temporary employment status in such a manner that the parents' lower education level and lower socio-economic status first hamper their children's human capital accumulation and then lead them to take up inferior positions to gain high skills in an occupation commonly designed as temporary employment. Using the data of 2017 individuals from the World Bank's Step Skills Measurement Survey conducted in China, we find evidence to support our two-stage mediating model.

Keywords Temporary employment choice · Family background · Chain mediation model

109.1 Introduction

The Chinese labor force is changing as non-standard employment is becoming increasingly popular. From a survey conducted by consulting firm Mercer in 2010 covering 738 firms in Greater China, 71 % firms reported that they adopt non-standard employment practices (by employing temporary workers, part-time workers, and independent contractors) and over 49 % employers indicated that they would consider employing temporary workers the next year. Despite the wide adoption of non-standard employment in practice, few studies in the literature examine this type of employment in China.

Non-standard employment is a general concept referring to all types of flexible work other than standard employment and includes temporary workers, part-time workers, independent contractors, and free-lancers. Because of differences in length

X. Qian · X. Zheng · H. Zhou (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: zhouhao@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_109

of contracts and expectations of continued employment between types of nonstandard work, scholars have argued the existence of different treatments and impacts on work outcomes, hence should be studied distinctively [11]. In this study, we focus on a particular type of nonstandard employment, temporary work.

Despite the large volume of the literature regarding the impact of temporary employment on individual's attitude, behavior and work outcomes such as organizational commitment, turnover intention, performance, OCB, withdrawal behavior [8, 11], there is rare discussion exploring the factors influencing an individual's choice of temporary employment. One relevant topic is the personal choice of flexible work arrangements (flexible working hours) [1, 26]. These studies provide evidence that female workers are more likely to choose flexible working hours in order to balance their family and work. Factors influencing the choice of temporary employment (short-term labor contracts) are more complicated. Jong et al. [12] and Gustafsson et al. [18] discussed temporary employment from the perspective of individual motives and found that work-related variables such as occupational position, tenure, and employability, besides the individual variable, significantly influence an individual's employment choice. They argue that some workers accept temporary jobs in order to avoid unemployment or to gain permanent employment because they find it difficult to find permanent employment. Proceeding further in Jong et al. [12] and Gustafsson et al. [18]'s argument, we discuss how family background disadvantages diminish the ability of workers to obtain regular employment, and in turn increase the likelihood of individual's acceptance of temporary employment arrangements.

This study will contribute the literature in two ways. First, this study will fill the gap in the literature on the discussion of temporary employment in the labor force in China. Second, this study will explore a mechanism how family background will influence individual's choice of temporary employment, which has been ignored in previous literature. The structure of the paper is as follows. In Sect. 109.2, we briefly introduce the practice of temporary employment in China. In Sect. 109.3, we propose the research hypotheses. The data collection and variables used in the analysis are introduced in Sect. 109.4. We present regression results and discussion respectively in Sects. 109.5 and 109.6.

109.2 Temporary Employment in China

According to Kalleberg et al. [19], temporary workers are those who work full-time in a firm but whose work is a short-term supplement to a firm's regular workforce. In the Chinese management practices, no clear distinction exists between the concepts of contract workers, temporary workers, and short-term workers, and all the three terms are used to define this particular type of employment.

In China, regular workers, sometimes called permanent workers, are those who not necessarily work for one employer permanently, but, once they are employed, the expectation is that they would stay long with the employer and seek career development within the company. In contrast, for temporary employment, the contract term is much shorter, usually several months. This type of worker is expected to leave the employer once the contract period is over and may refer to disparate types of job arrangements [5].

Two major temporary employment types are found in China, agency temporary workers and direct-hire temporary workers. The difference between the two types lies in whether or not the workers have legal status in the organization they serve.

Consistent with their description in the United States and European studies, temporary workers in China's management structure are also treated disparately. Some disparate treatment can be visually distinguished, for example, through physical distinctions such as special colored uniforms or ID badges and policy distinctions such as less involvement in training programs and no opportunities to participate in award ceremonies or group tours of firms. No obvious large differences exist in the explicit or implicit policies toward temporary and regular workers; for example, temporary workers generally face fiercer competition in promotions, receive lower payment and less insurance or other benefits, and yet are assigned more undesirable tasks.

A large volume of the literature addresses the wage and benefit differences between temporary workers and regular workers in the United States and the European countries such as Spain. The findings of wage difference are not conclusive. Görg and Görlich [17] found that wages are substantially lower in part-time jobs than in full-time jobs. After correcting for the selection of part-time work, the wage differences are seen to increase. Cohen and Haberfeld [7] found that after controlling for the demographic and human capital variables, no significant wage difference exists between temporary and regular workers. Studies on European countries have reported variation in payments across countries [18].

With regard to differences in benefits between the two types of workers, scholars draw a consistent conclusion that temporary workers receive less benefit, less training, and less promotion opportunities. Barker and Christensen [2] reported that contingent workers are less likely to be eligible for health insurance and pension compared to regular workers. Lautsch [21] explored the influential factor of benefit provision for contingent workers and finds that job design and internal labor market rules are the two major driving forces.

Evidence on China's temporary employment is rare. Chen [5] discussed the inferior position of nonstandard workers in China, but did not provide much empirical evidence. A body of the literature available for reference is the studies on informal employment in China. Workers in the informal sectors are featured with no formal labor contract or self-employment status and are distinguished from temporary workers. Studies on informal employment in China have found that compared to formal workers, informal workers experience longer working hours but receive lower wages and benefits [27].

The 2012 Step Skills Measurement Survey of the World Bank on the Yunnan Province identifies the individuals who entered the temporary employment arrangement. Table 109.1 shows the treatment disparities between permanent workers and temporary workers in China, including the difference in working hours, wages, benefits, training opportunities, and job characteristics.

Table 109.1 Treatment disparity between regular workers and temporary workers

	Regular workers	Temporary workers	Wilcoxon singed-rank test
Disparity in treatment			
Hours worked weekly	44.17	45.43	$z = -2.45$ ($p = 0.0143$)
Income	2412.46	1740.18	$z = 9.10$ ($p = 0.0000$)
Formal contract	0.77	0.37	$z = 1.75$ ($p = 0.0000$)
Coverage of social insurance	0.69	0.23	$z = 12.48$ ($p = 0.0000$)
Training			
Tenure in current job (month)	115.21	61.24	$z = 7.46$ ($p = 0.0000$)
Training in last 12 months	0.19	0.08	$z = 3.78$ ($p = 0.0002$)
Job characters			
Drives a vehicle at work	0.3	0.2	$Z = 2.90$***
Repairs or maintains electronic equipment at work	0.22	0.11	$Z = 3.46$***
Operates heavy machinery or industrial equipment	0.05	0.04	$Z = 0.50$
Contact with people other than coworker score	2.11	1.87	$Z = 3.22$***
Frequency of computer use at work	1.8	0.85	$Z = 8.94$***
Supervises others at work	0.51	0.32	$Z = 5.02$***
Makes presentations at work	0.53	0.4	$Z = 3.62$***
Frequency of thinking and learning tasks	1.32	1.03	$Z = 4.31$***
Autonomy at work score	1.35	1.14	$Z = 4.15$***
Repetitiveness at work score	0.54	0.53	$Z = 0.72$
Lift heavy items at work score	1.27	1.54	$Z = -3.91$***

Data source STEP Skills Measurement Survey in Yunnan, China, 2012 by The World Bank;*** indicates that the figure is significant at the 1 % level, ** indicates significant at the 5 % level, * indicates significant at the 10 % level

109.3 Hypotheses

Intergenerational mobility is a widely discussed topic, Scholars provided empirical evidences for the earnings and education persistence between generations [13]. The literature documents two mechanisms to examine the intergenerational correlation of labor market outcomes in a well-functioning labor market. On one hand, employers favor more qualified applicants given a certain level of labor cost, and children from wealthy or well-educated families generally have better human capital accumulation and are more likely to gain superior employment status. A large volume of the literature found that the education and income levels of parents influence the education and income levels of their children [4, 22]. On the other hand, families having parents with higher socio-economic status are more likely to have connections with employers (social capital) and tend to use their connections to get better jobs for their children. Li et al. [24] used CCSS data covering the labor market performance of over 6000 Chinese undergraduate students. They found that the political capital of parents, that is, the cadre of parents, significantly increases the wage of children in their first job. The inequality in parents' education and socio-economic status influences the inequality of children in the labor market through human and social capital transmission. Children from lower socio-economic families have disadvantages in the labor market and hence are more likely to accept lower employment status and take up temporary employment.

We next discuss the human capital transmission path. The education literature has found that cognitive and non-cognitive skills are formed in the early stages of children's development and the effect of human capital investment is better in those earlier stages [20]. Formal school education and informal household education are crucial in the human capital accumulation of children. Previous studies have found that family income and parental characteristics such as education, political connection, and occupation are all important factors influencing household educational expenditure. In China, where private educational investment accounts for a large part of children's educational investment, less investment in education has a negative influence on the educational opportunities and outcomes of children [16]. Furthermore, well-educated parents provide better household education; studies have found that children are significantly more willing to learn when their parents are better educated [23].

According to the classic Person-Job fit theory, in a well-functioning labor market, each organization maximizes its economic value by selecting employees with abilities that match the demands of the job [14]. Hence, candidates with a lower level of education and less cognitive and non-cognitive skills are not likely to stay in positions requiring high skills.

Since knowledge and skills are the key factors in value creation, as the development of information technology could change the nature of work within organizations, organizations could reap the cost and flexibility advantages of nonstandard workers [19]. Davis-Blake and Uzzi [10] argued that the type of work determines the employment conditions of workers. Non-standard employment arrangements may

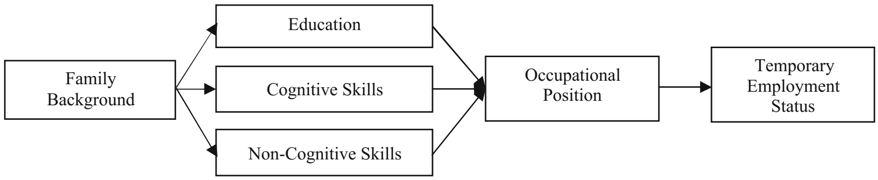


Fig. 109.1 Research model

create two classes of employees: permanent workers performing jobs involving high technical or informational complexity, such as innovative jobs [28], and temporary workers who perform simple, repeated, low-paying jobs. This division arises from the difficulty of managers to monitor complex jobs and their higher expectation of discretionary effort by employees. Consistent with this argument, Jong et al. [12] and Felstead and Gallie [15] found that part-time and temporary employees on average are given less-skilled jobs than those working on full-time and permanent contracts. Previous analyses based on the Social Change and Economic Life Initiative (SCELI) survey found that the job demand of part-time work, on average, requires lower qualifications and shorter periods of training, and can be learnt relatively quickly.

Jong et al. [12] argued that in addition to those who voluntarily accept temporary employment, some workers are forced to accept temporary job because of the difficulty to find permanent employment. In order to avoid unemployment or as a means to gain permanent employment (stepping-stone motive), some workers accept a temporary job with lower work status. They provide evidence that education level and occupational positions are factors influencing the temporary employment choice of individuals.

From the preceding arguments, we have the following hypotheses:

Hypothesis 1 (H1): Family background has a significant impact on the temporary employment choice of children such that higher education levels and family socio-economic status significantly reduce an individual's likelihood of temporary employment.

Hypothesis 2 (H2): Human capital (education as well as cognitive and non-cognitive skills) and occupational position mediate the effects of family background on temporary employment status sequentially (Fig. 109.1).

109.4 Method

109.4.1 Data

As part of The Skills Towards Employability and Productivity (STEP) program, the World Bank conducted the STEP Skills Measurement Survey in Yunnan Province in China in 2011–2012; the survey covered 2017 individuals from 1021 households in Yunnan.

In order to ensure that interviewed households were randomly distributed in the population, the sample were selected via stratified random sampling method. The surveyed individuals reported their household information, educational level, health, employment, work skills, personality, behavior, and preferences in 2012.

109.4.2 Measures

Temporary Employment Status: The survey asked respondents whether "the main job of the past week was seasonal, occupational, temporary, permanent/long-term, or fixed-term"; we treated the first three categories as "temporary employment" and the other two as permanent employments. Therefore, the variable "temporary employment" is a dummy variable, with temporary worker equal to 1 and permanent worker equal to 0.

Skill Level of Jobs: The respondent's occupational information was first collected according to the International Standard Classification of Occupations (ISCO). The STEP further aggregated the occupations into five categories according to the skill level required for the job. The STEP occupation types indicate the skill level of jobs.

Family Background: In module 7 of the survey "Language and family," the respondents were asked to assess their families' socio-economic status at age 15 and to report the educational level of their father and mother; a summary index is constructed using a score ranging from 1 (low SES/below high school education) to 3 (high SES/ above high school education) for each of the three aspects of family background and then taking the average of the summed scores. We obtain a statistically robust index with a Cronbach's Alpha of 0.52. The inclusion of another aspect of family background, "number of family economic shocks before your 15 years of age," reduces the alpha statistic by one point. We therefore decide to exclude this from the family background index. However, the pattern of results is not sensitive to this reduction.

Education: Following previous studies [6], we take the years of education as measure of educational level of respondents. Years of education is calculated from the reported educational attainment. We also run the regression model with educational level as measure of education; the pattern of estimation is consistent.

Cognitive skills: We take the average of the computer, writing, reading, and numeracy skill dummies to derive the cognitive skill index, with 1 as the maximum of cognitive skill and 0 the minimum. This index is statistically robust with a Cronbach's Alpha of 0.71.

Non-cognitive skills: The respondents were asked 24 questions about how they assess themselves in a rating scale of 1 to 4, from "Almost never" to "Almost always," such as "Are you talkative?" and "Are you generous to other people with your time or money?" The STEP sums the 24 questions into five personality types: extraversion, conscientiousness, openness, neuroticism, and agreeableness (based on a classic personality theory known as "Big Five"). From among the five independent personality types, conscientiousness refers to the personality trait of being thorough, careful, or vigilant; it implies a desire to do a task well and has the most explanatory power of work outcome [25]. Thus, we adopt conscientiousness as measure of a person's non-cognitive skills.

Control variables: The demographic variables such as age, gender, and marital status are considered important factors influencing an individual's decisions and thus are incorporated in our model as control variables.

109.5 Results

109.5.1 Descriptive Statistics

Table 109.2 presents the means, standard deviations, correlations, and scale reliabilities for the variables in this study. As predicted, temporary employment is significantly and positively correlated to occupation type ($r = 0.20$, $p < 0.01$), which in turn is significantly and negatively related to years of education ($r = -0.42$, $p < 0.01$) and cognitive skills ($r = -0.42$, $p < 0.01$). Consistent with the prior literature, family background is negatively related to temporary employment ($r = -0.13$, $p < 0.01$) but positively related to years of education ($r = 0.29$, $p < 0.01$) and cognitive skills ($r = 0.19$, $p < 0.01$).

109.5.2 Regression Analysis Result

Through a series of hierarchical regression analyses, we test our hypotheses. As Table 109.3 shows, after controlling the effect of the control variables (age, gender, and marital status), we find family background negatively related to temporary employment status ($b = -0.174$, $p < 0.001$). Thus, hypothesis 1 is supported.

Following Baron and Kenny [3], we conduct a series of hierarchical regression analyses tests on the chain mediation model. The first phase of the model is tested as shown in Table 109.4. The control variables (age, gender, and marriage status) are first entered in the regression model (M1) and then the independent variable (family background) is entered in the regression model (M2). Family background is negatively related to occupational position ($b = -0.130$, $p < 0.001$) but positively and significantly associated with years of education ($b = 0.203$, $p < 0.001$, M3), cognitive skill ($b = 0.127$, $p < 0.001$, M4), and conscientiousness ($b = 0.066$, $p < 0.05$, M5). After including years of education, cognitive skill, and conscientiousness in the regression equation respectively, the significant effect of family background on occupational position becomes weak ($b = -0.049$, $p < 0.1$, M6; $b = -0.082$, $p < 0.001$, M7; $b = -0.126$, $p < 0.001$, M8), and, at the same time, the significant effect of family background on occupational position becomes insignificant ($b = -0.045$, ns, M9). Therefore, we conclude that the effect of family background on

Table 109.2 Correlations, alpha, mean, and standard deviation

Variables	M	SD	1	2	3	4	5	6	7	8	9
1. Temporary employment	0.21	0.41	1								
2. Occupational position	2.1	0.96	0.20**	1							
3. Years of education	12.95	3.4	−0.25**	−0.42**	1						
4. Cognitive skills	0.75	0.31	−0.27**	−0.42**	0.57**	−0.71					
5. Conscientiousness	3.17	0.45	−0.13**	−0.07	0.12**	0.11**	1				
6. Family background	2.38	0.73	−0.13**	−0.17**	0.29**	0.19**	0.06	−0.52			
7. Age	39.57	9.4	0.08**	0.16**	−0.33**	−0.25**	0.004	−0.25**	1		
8. Male	0.49	0.5	0.005	−0.09**	0.17**	0.13**	0.04	0.12**	−0.13**	1	
9. Has spouse	0.81	0.39	0.03	0.12*	−0.16*	−0.06	0.004	−0.12**	0.33**	0.03	1

*** indicates that the figure is significant at the 1 % level, ** indicates significant at the 5 % level, * indicates significant at the 10 % level

Table 109.3 Results of the relationship between family background and temporary employment

	(1)	(2)
	Temporary employment status	Temporary employment status
Control variables		
Age	0.117**	0.077*
Gender	0.022	0.037
Has spouse	0.001	−0.004
Independent variable		
Family background		−0.174***
R^{2*}	0.007	0.02
$\triangle R^2$		0.013***
Chi2 tests		14.22***
Observations	1045	1045

Notes 1. Standardized coefficient estimates and the significance level are reported. *, **, and *** indicate significance at the 10, 5, and 1 % levels, respectively. Due to limited space, the standard error estimates are not reported but can be obtained from the authors upon request
2. Columns (1) and (2) are estimated by Probit model; the Pseduo R2 is reported. The Chi2 test of improvement for goodness of fit is reported

occupational position is completely mediated by years of education, cognitive skill, and conscientiousness.

Using the same procedure, we test the second phase of the chain mediation model. The results are presented in Table 109.5. The control variables (age, gender, and marriage status) are first entered in the regression model (M10) and then the independent variables (years of education, cognitive skill, and conscientiousness) are entered in the regression model (M11). Years of education, cognitive skills, and conscientiousness are negatively related to temporary employment ($b = -0.210$, $p < 0.001$; $b = -0.222$, $p < 0.001$; $b = -0.285$, $p < 0.001$). While years of education and cognitive skills are negatively associated with occupational position ($b = -0.258$, $p < 0.001$; $b = -0.280$, $p < 0.001$, M12), conscientiousness has no significant effect on occupational position ($b = -0.002$, ns, M12). After including occupational position in the regression equation, while the effect of years of education on temporary employment became weak ($b = -186$, $p < 0.001$, M13) and the effect of cognitive skills on temporary employment also became weak ($b = -0.193$, $p < 0.001$, M13), the effect of conscientiousness on temporary employment became even stronger ($b = -0.130$, $p < 0.001$, M13). In conclusion, the effects of years of education and cognitive skills on temporary employment are partially mediated by occupational position. Conscientiousness has a direct negative influence on temporary employment.

From the above results, while years of education, cognitive skills, and conscientiousness have mediated the relationship between family background and occupational position, occupational position has mediated the relationship between years of education, cognitive skills, and temporary employment. Thus, our chain mediation model is partially supported. The complete results of this study are shown in Fig. 109.2.

Table 109.4 Results of mediated relationship between family background and occupational position

	(1) Occupational position	(2) Occupational position	(3) Years of education	(4) Cognitive skills	(5) Non-cognitive skills	(6) Occupational position	(7) Occupational position	(8) Occupational position	(9) Occupational position
Control variables									
Age	0.116***	0.087***	−0.249***	−0.211***	0.024	−0.013	0.0003	0.092***	−0.032
Gender	−0.079**	−0.068**	0.117***	0.088***	0.033	−0.021	−0.034	−0.064**	−0.014
Has spouse	0.087***	0.081**	−0.054*	0.018	0.003	0.060**	0.088***	0.085***	0.076***
Independent variable									
Family background		−0.130***	0.203***	0.127***	0.066**	−0.049*	−0.082***	−0.126***	−0.045
Mediating variables									
Years of education	–	–	–	–	–	−0.399***	–	–	−0.279***
Cognitive skills	–	–	–	–	–	–	−0.399***	–	−0.249***
Non-cognitive skill	–	–	–	–	–	–	–	−0.055*	−0.0004
R^2	0.03	0.05	0.17	0.09	0.01	0.18	0.2	0.06	0.24
$\triangle R^2$		0.02				0.13	0.15	0.01	0.19
F-tests		17.23***				168.12***	187.52***	3.27**	75.19***
Observations	1045	1045	1045–1043	1044	1045	1043	1044	1042	

Notes 1. Standardized coefficient estimates and significance levels are reported. *, **, and *** indicate significance at the 10, 5, and 1 % levels, respectively. Because of limited space, the standard error estimates are not reported, but can be obtained from the authors upon request
2. The F-tests for improvement of goodness of fit are reported

Table 109.5 Results of the mediating role of occupational position

	(10) Temporary employment status	(11) Temporary employment status	(12) Occupational position	(13) Temporary Employment status
Control variables				
Age	0.117**	−0.017	−0.016	−0.016
Gender	0.022	0.079*	−0.024	0.080*
Has spouse	0.001	−0.001	0.076***	−0.009
Independent variable				
Years of education		−0.210***	−0.258***	−0.186***
Cognitive skills		−0.222***	−0.280***	−0.193***
Non-cognitive skills		−0.285***	−0.002	−0.130***
Mediating variables				
Occupational position				0.101**
R^{2*}	0.007	0.095	0.236	0.1
$\triangle R^2$		0.088		0.004
F-tests/Chi2 tests		89.71***		4.81**
Observations	1045	1043	1043	1043

Notes 1. Standardized coefficient estimates and significance levels are reported. *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively. Because of limited space, the standard error estimates are not reported, but can be obtained from the authors on request
2. Columns (10), (11), and (13) are estimated by Probit model; the Pseduo R^2 is reported. For the Probit model, the Chi2 tests of improvement for goodness of fit are reported, and for the ordinary least squares (OLS) model, the F-tests are reported
3. Occupational position is treated as the continuous variable in the OLS model in Column (12). The estimates of the Mprobit model, which treats occupational position as categorical variables, is consistent with that in column (12). To examine the mediating effect, we report the OLS regression estimates to examine the effect of education and cognitive and non-cognitive skills on occupation

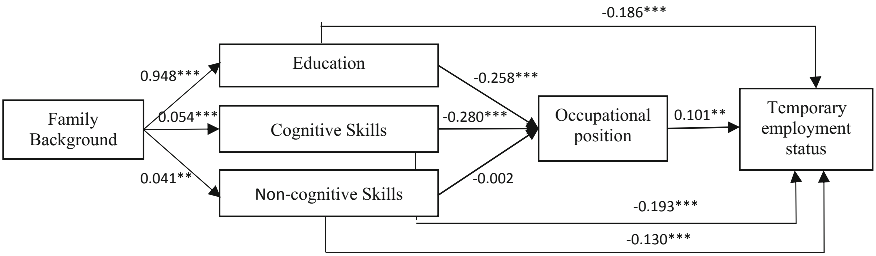


Fig. 109.2 Completely standardized parameter estimates (*Note* $^{*}P < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$)

109.6 Discussion

This study tried to answer the important question of how disadvantages of family background diminish the ability of workers to obtain regular employment. From the intergenerational mobility theory, we propose a chain mediation model to show how the mechanism of family background impacts an individual's temporary employment status in such a manner that parents' lower education level and socio-economic status first hamper the human capital accumulation of children and then lead them to inferior positions to gain high skills in an occupation commonly designed by the organization as temporary employment.

We use the World Bank survey data for a two-stage model to provide evidence for the sequential mediating effect of an individual's human capital and occupation skill level on the relationship between family background and the individual's temporary employment status.

The potential limitation of this study is the ad hoc nature of the measure of the key variable, cognitive skills. We measure this construct with self-reported conscientiousness, one aspect of the Big Five personalities. Clearly, this does not cover the entire domain of non-cognitive skills. Using non-cognitive skills is a delicate procedure that is seriously discussed by scholars [9].

Future research may want to address how family background influences an individual's temporary employment status, that is, how parents use their social network to help their children obtain superior employment status.

Acknowledgments The authors thank for the support by the National Science Foundation of China (grant no. 71402108, 71472129, 71302182), the Humanities and Social Sciences Foundation of the Ministry of Education (grant no. 14YJC630103), and the Philosophy and Social Science Fund of the Sichuan Province (grant no. SC14C017).

References

1. Almer ED, Cohen JR, Single LE (2003) Factors affecting the choice to participate in flexible work arrangements. Audit: J Pract Theory 22(1):69–91
2. Barker K, Christensen K (1998) Contingent work: American employment relations in transition. Cornell University Press, New York
3. Baron RM, Kenny DA (1986) The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations. J Pers Soc Psychol 51(6):1173
4. Black SE, Devereux PJ, Salvanes KG (2005) Why the apple doesn't fall far: understanding intergenerational transmission of human capital. Technical Report 95, American Economic Review
5. Chen J (2003) Offshoring, wages and job security of temporary workers. Econ Perspect 5:59–63
6. Chi W, Qian X (2010) The role of education in regional innovation activities: spatial evidence from China. J Asia Pac Econ 15(4):396–419
7. Cohen Y, Haberfeld Y (1993) Temporary help service workers: employment characteristics and wage determination. Ind Relat: J Econ Soc 32(2):272–287
8. Connelly CE, Gallagher DG (2004) Emerging trends in contingent work research. J Manag 30(6):959–983

9. Cunha F, Heckman JJ (2008) Formulating, identifying and estimating the technology of cognitive and noncognitive skill formation. J Hum Resour 43(4):738–782
10. Davis-Blake A, Uzzi B (1993) Determinants of employment externalization: a study of temporary workers and independent contractors. Adm Sci Q 38:195–223
11. De Cuyper N, De Jong J et al (2008) Literature review of theory and research on the psychological impact of temporary employment: towards a conceptual model. Int J Manag Rev 10(1):25–51
12. De Jong J, De Cuyper N et al (2009) Motives for accepting temporary employment: a typology. Int J Manpow 30(3):237–252
13. De Nardi M, Yang F (2015) Wealth inequality, family background, and estate taxation. J Monet Econ
14. Edwards JR (1991) Person-job fit: A conceptual integration, literature review, and methodological critique. Wiley, New York
15. Felstead A, Gallie D (2004) For better or worse? Non-standard jobs and high involvement work systems. Int J Hum Resour Manag 15(7):1293–1316
16. Filmer D, Pritchett L (1999) The effect of household wealth on educational attainment: evidence from 35 countries. Popul Dev Rev 25(1):85–120
17. Görg H, Görlich D (2012) Offshoring, wages and job security of temporary workers. Rev World Econ 1–22
18. Gustafsson EK, C W, (2015) Employment choices and pay differences between non-standard and standard work in Britain, Germany. Netherlands and Sweden. Technical Report 33
19. Kalleberg AL (2000) Nonstandard employment relations: part-time, temporary and contract work. Annu Rev Soc 341–365
20. Krassel KF, Sørensen KL (2015) Childhood and early labor market life-cognitive and noncognitive skills and their return to labor market outcomes. NBER
21. Lautsch BA (2003) The influence of regular work systems on compensation for contingent workers. Ind Relat: J Econ Soc 42(4):565–588
22. Li W (2007) Family background, financial constraints and higher education attendance in China. Econ Educ Rev 26(6):724–734
23. Liu Y (2010) The impact of parents' education on children's primary school outcome: An empirical study using western five province household data. In: Education economic annual conference in China (in Chinese)
24. Li H, Meng X, Wu B (2012) Parental political capital and children's labor market performance: evidence from the first job offers of Chinese college graduates. China Econ Q 3:012
25. Salgado JF (1997) The five factor model of personality and job performance in the European community. J Appl Psychol 82(1):30
26. Stavrou E, Ierodiakonou C (2011) Flexible work arrangements and intentions of unemployed women in Cyprus: a planned behaviour model. Br J Manag 22(1):150–172
27. Wu Y, Cai F (2006) Informal employment in urban China: size and characteristics. China Labor Econ 3(1):67–84
28. Zhou H, Dekker R, Kleinknecht A (2011) Flexible labor and innovation performance: evidence from longitudinal firm-level data. Ind Corp Chang 20(3):941–968

Chapter 110
Analysing Influences Factors of Knowledge Transfer Between University and Industry

Zezhong Wu and Bin Ma

Abstract The aim of the study was to analyze the influence factors of knowledge transfer between university and industry. Then, the 197 valid questionnaires selected from the empirical survey are analysed. Combined with the multivariate statistical analysis, we have screed out 6 factors including 31 indicators of influencing knowledge transfer between university and industry. In order to further analyse the factors that influence the degree of knowledge transfer, a structural equation may be established to test the influence degree by means of selecting indicators. Then we calculate the value of six first-level indicators and give subjective weights to the indicators by AMOS 7.0. Through several adjustments, optimal structural equation model is established. Further, we analysed the influence degree of all the affecting factors on knowledge transfer between university and industry. This approach provides a new perspective for scientific and technological evaluation in general sense. It should be noted that the availability of basic data and the rationality of modelling bear much upon the evaluation results.

Keywords Knowledge transfer · Structural equation modelling · University and industry

110.1 Introduction

The importance of university knowledge for the process of industrial innovation has been widely studied. Some consensus seems to exist on the positive impact of academic research on the development of industrial innovation [13]. In particular, some authors have shown that around 10 % of the new products and processes introduced by firms would not have been developed (or only with great delay) without the contribution of academic research [2, 7, 8]. Still, no consensus is found on the role of

Z. Wu (✉) · B. Ma
Applied Mathematics School, Chengdu University of Information Technology,
Chengdu 610225, People's Republic of China
e-mail: 450856710@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_110

universities in the development of industrial innovations, or on the channels through which knowledge flows between universities and industrial firms. Some authors argue that firms consider codified output, such as publications and patents, the most important form of accessible knowledge that is being developed by the university. For instance, Narin et al. [12] found that 73 % of the papers cited in US industry patents were published by researchers working for public research organizations, while the remaining were authored by industrial scientists.

Several empirical studies have analysed the process of knowledge transfer between universities and firms by focusing on several different aspects of this process. These studies have produced contrasting evidence concerning the importance of different types of knowledge outputs of universities to firms. On the one hand, codified output of academic research like publications and patents seem to be the most important input to industrial innovation [4, 10, 12]. On the other, collaborative and contracted research activities appear to be a much more important form of knowledge transfer [6, 11]. Moreover, the employment of university researchers is described as an effective way to transfer knowledge from universities to firms [5]. Next, informal contacts are often found to be a common form of interaction between universities and industry [1, 4, 9].

While all knowledge transfer faces some obstacles, cross border Knowledge transfer faces extra challenges due to cross-cultural, political, economic, and geographical gaps. Knowledge sharing is often seen as resulting in a loss of power, and, as a result, knowledge that should be transferred is often withheld, leading to inefficiency. Therefore, many researchers focus on influence factors of the cooperation knowledge transfer between university and industry, or pay attention to influence factors of knowledge transfer from university to industry. Cohen and Levinthal [3] thought that knowledge transfer from university to industry related with absorption capacity of the firm. Trust, geographical similar, diversion channels, intellectual property, patent and technology licensing policy is believed to affect positive knowledge transfer from university to industry [14]. Study found that impediments to knowledge transfer from university to industry, include cultural factors, informal barriers, improper staffing, the lack of practical experience, as well as lack of incentives for technology holders [15]. However, most of these studies focus only on knowledge transfer from university to industry, while ignoring two-way flow of knowledge of the industry-university collaborative innovation mode, and lack quantitative research.

In this paper, we aim to analyse influence of the various factors on knowledge transfer between university and industry. For this purpose, this paper will use data collected via a questionnaire in the China. One addresses industrial researchers, the other academic researchers. We also want to highlight the fact that the data used in this paper refers to information provided by R&D performers rather than by their managers or superiors. This way, we aim at improving our understanding of the importance of different influences on knowledge transfer between university and industry by surveying the actual university-industry knowledge innovation alliance.

This paper is organized as follows. In Sect. 110.1, we review the literature on the research of the university-industry knowledge transfer, and the literature on the factors affecting knowledge transfer. In Sect. 110.2, by means of factor analysis, factors affecting knowledge transfer between university and industry is selected. In Sect. 110.3, a structural equation model was built to analyse influence of the various factors on knowledge transfer between University and Industry. Section 110.4 concludes this paper and makes recommendations for policy and management.

110.2 Building Indicators of Influencing Knowledge Transfer

When analyzing the impact of knowledge transfer, we must give full consideration to the actual characteristics of the evaluation object. We chose six indicators as the basis for analysis of factors, including the transfer motivation, the partner selection, the transfer process, the transfer risk, the transfer conflicts coordination, transfer effect. Let six factors as structural variables, each evaluation index corresponding to structural variables as observable variables, we established a structural equation model of knowledge transfer influencing factors. Through empirical research, the influences were exist for six indicators, and detailed 6 level indicators, 33 secondary indicators were shown in Fig. 110.1.

110.2.1 Data Validity and Reliability Test

The analyses in this paper are based on original data collected from May to June 2013. We developed related questionnaires, aimed at university researchers and industry researchers. We again want to highlight the fact that the data used in this paper refers to information provided by R&D performers, which are the real users and developers of knowledge in the university and in industry, rather than R&D managers. The variables comprising the questionnaire are as below.

All items employed a seven-point Likert scale format where 1-7 indicated very unimportant and very important. Respondents include university researchers and industry researchers. Completed questionnaires were returned face-to-face by the respondents or directly mailed to the author. Hence, 210 out of 240 total surveyed represented a high valid response of 87.5 %. Among them, the effective questionnaires are 197, accounting for 82.08 % questionnaire. Among the participants approximately 47.7 % were university researchers and approximately 52.3 % were industry researchers.

For the above indicators of selection, through making the overall validity and reliability analysis for the measurement data, it obtains the later establishment foundation of structural equation model. The results are shown in Table 110.1. Reliability of the data is suitable for statistical analysis.

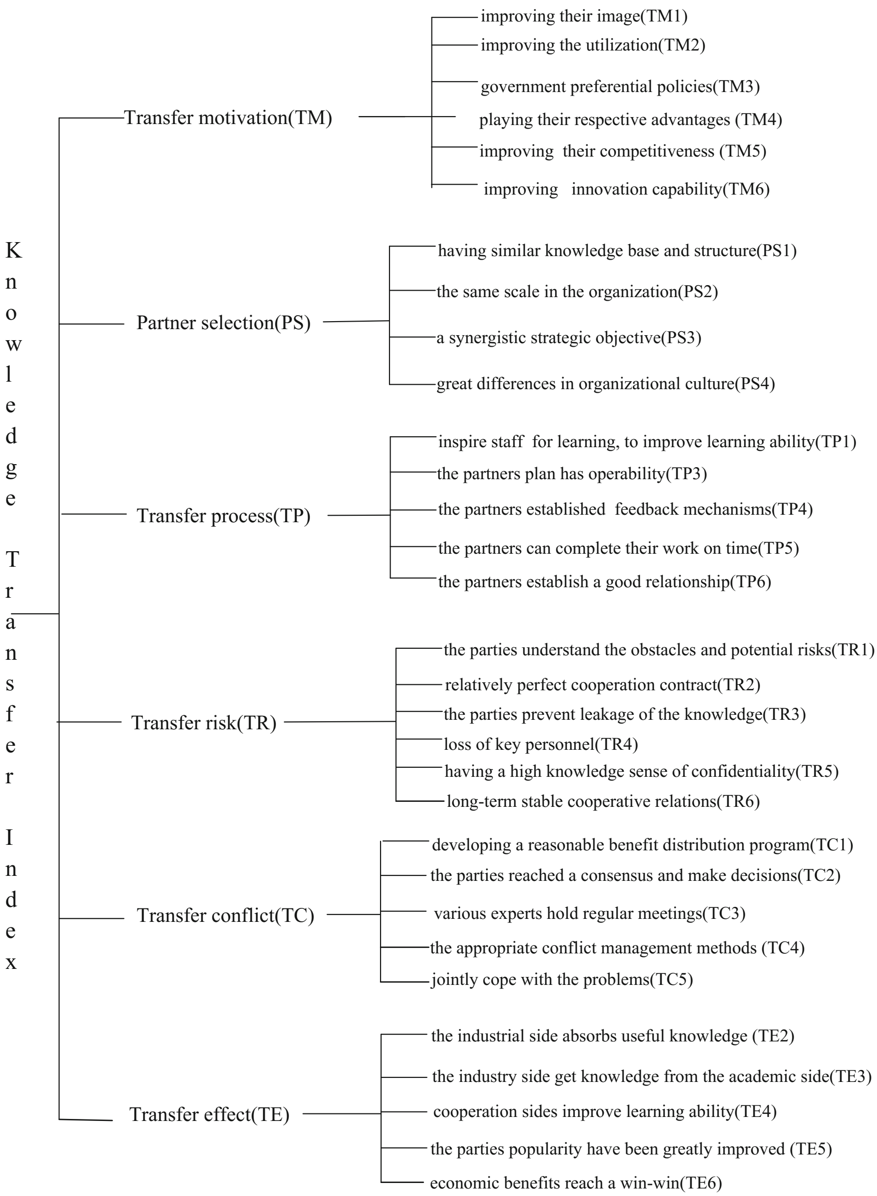


Fig. 110.1 Selection indicators

Table 110.1 Total and each project reliability statistics

	Total	TM	PS	TP	TR	TC	TE
Cronbach's Alpha	0.899	0.706	0.701	0.773	0.708	0.717	0.751
N	31	6	4	5	6	5	5

110.3 Developing Structural Equation Modelling

In order to further analyse the factors that influence the degree of knowledge transfer, in this section, a structural equation may be established to test the influence degree by means of selecting indicators. Then we calculate the value of six first-level indicators and give subjective weights to the indicators by AMOS 7.0. Through several adjustments, optimal structural equation model is established.

110.3.1 Evaluation Path Diagram of Knowledge Transfer

Based on the assumptions above, we built the structural equation-model path diagram. There are 31 observed exogenous variables; the number of the measurement data is DP 197.

As shown in Fig. 110.2, the setting condition of the entire model is as follows:

(1) There are 31 observed exogenous variables;
(2) there are 6 exogenous latent variables and 1 endogenous latent variables;
(3) there are 31 exogenous measurement residuals;
(4) endogenous latent variables are explained by the endogenous latent variables, namely the Beta matrix, with 1 structural equations;
(5) there are 31 observed exogenous factor load parameters;
(6) The first factor load parameters is set to be 1, and a total of six factor load parameters is set to be 1.

110.3.2 Model Output and Updating

Based on the assumptions above, the initial model output, the coefficients estimation results and the variance estimation are shown in Fig. 110.3, Tables 110.2 and 110.3.

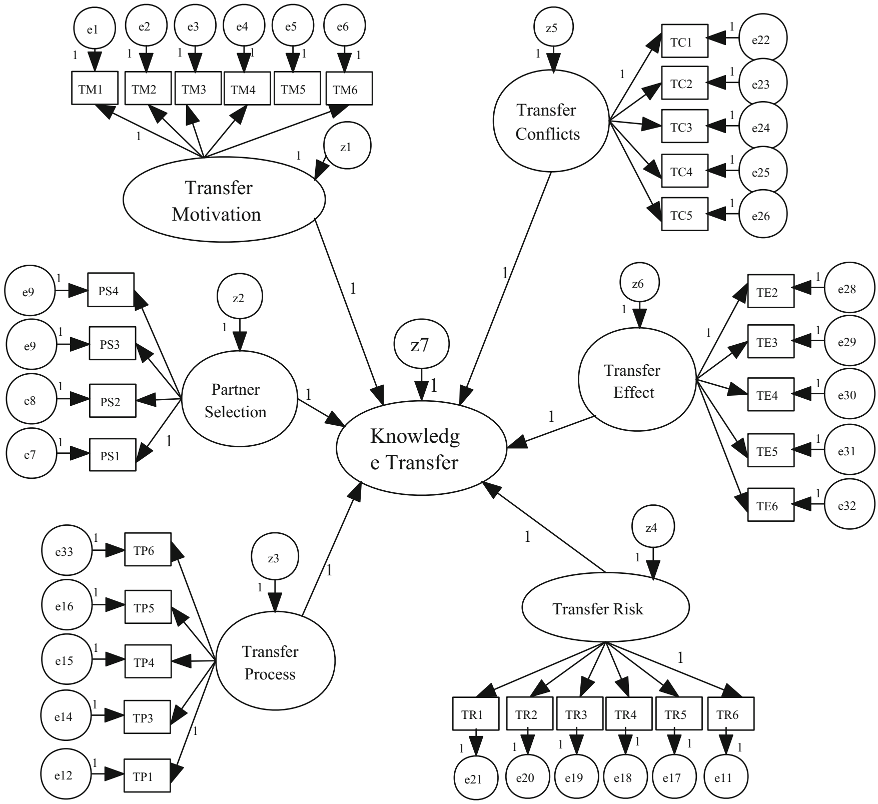


Fig. 110.2 SEM hypothesis model

110.3.3 Model Revision

The first goal of model evaluation is to estimate whether or not the results are statistically significant. We need to carry out statistical significance test for path coefficient and factor load parameters. AMOS provides us with C.R. (Critical Ratio), a Z-statistics, and we can also know the value of p. From Table 110.2, we can see that except for the path between "Partner Selection" and "PS4", the other path coefficients were significant. However, a considerable number of standardized path coefficients show that the path coefficient values are generally lower than we expected.

Second, the fitting degree of the model has to be evaluated. The fit index mainly examines whether or not the model matches data. The standard requirement of this model fitting evaluation is to evaluate the smallest model parameters between the variance-covariance matrix of the sample and the matrix in theory. Namely, the closer to 0 of the parameter, the fitting degree is higher of this model; otherwise, we need to correct index of this model.

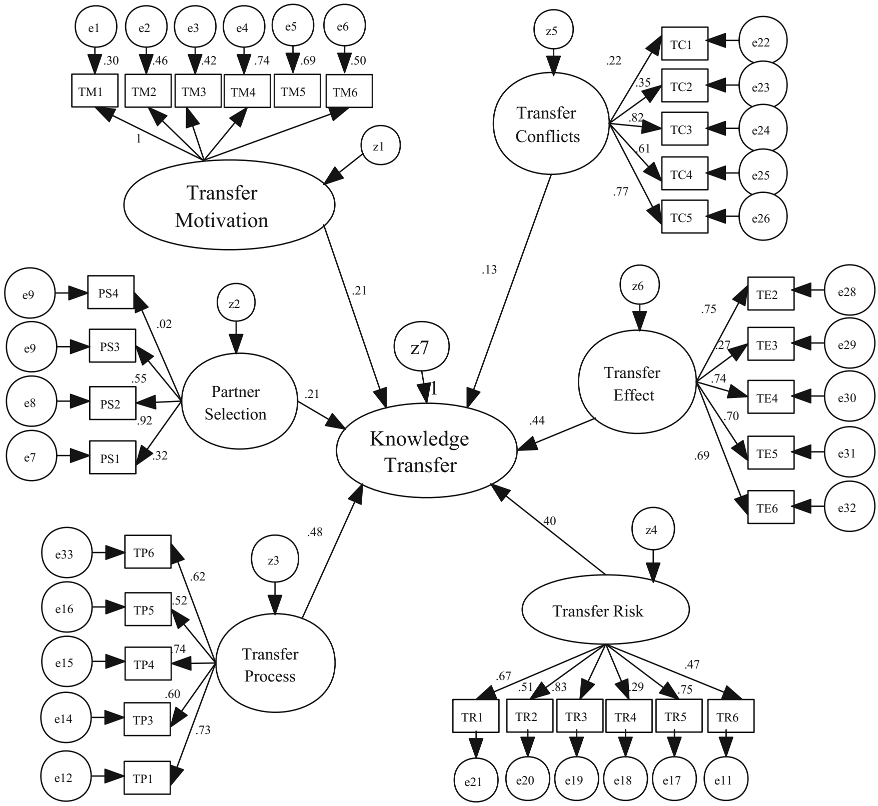


Fig. 110.3 Standardized parameter estimation result

As shown in Table 110.4, the fit index of the initial model only partly meets the need of the required fitting degree. In this condition, we considered to remove the path of "Partner Selection" and "PS4", re-correcting the model. The results are shown in Figs. 110.4 and 110.5. The regression weights and variances are shown in Tables 110.5 and 110.6.

The fitting degree of the revision model (1) has to be evaluated as Table 110.7.

From Table 110.7, fit indices has not changed. Therefore, we need modification index. The so-called modification index is the reduced value of the chi-square of the entire model when the restricted model parameters are allowed freedom of estimation. The MI of the transfer process to the transfer risk is 121.950, which means that if we add a path between the transfer process to the transfer risk, the chi-square value of the model will be greatly reduced. From a practical perspective, the changes of TP1, TP3, TP4, TP5 and TP6 can all lead changes in the index of transfer risk. Next, we will focus on the modification of observed index. First, MI of e4 and e5 is 52.345, indicating that the addition of the path between e4 and e5 will greatly reduce the chi-square value. This phenomenon is easy to explain: TM4 is among TM5, and it

Table 110.2 Results of the coefficients estimation

			Non-standardized	S.E.	C.R.	P	Standardized
TM1	←	Transfer motivation	1.000				0.304
TM2	←	Transfer motivation	1.652	0.507	3.257	0.001	0.459
TM3	←	Transfer motivation	1.359	0.432	3.142	0.002	0.416
TM4	←	Transfer motivation	2.181	0.603	3.616	***	0.745
TM5	←	Transfer motivation	2.156	0.600	3.595	***	0.694
TM6	←	Transfer motivation	1.645	0.491	3.350	***	0.502
TE2	←	Transfer effect	1.000				0.749
TE3	←	Transfer effect	0.470	0.137	3.436	***	0.272
TE4	←	Transfer effect	1.114	0.123	9.032	***	0.744
TE5	←	Transfer effect	0.999	0.116	8.604	***	0.698
TE6	←	Transfer effect	0.962	0.113	8.537	***	0.692
TC1	←	Transfer conflict	1.000				0.220
TC2	←	Transfer conflict	1.592	0.656	2.427	0.015	0.351
TC3	←	Transfer conflict	3.508	1.265	2.772	0.006	0.817
TC4	←	Transfer conflict	3.974	1.466	2.712	0.007	0.605
TC5	←	Transfer conflict	4.370	1.577	2.771	0.006	0.774
PS1	←	Partner selection	1.000				0.316
PS2	←	Partner selection	3.412	1.351	2.525	0.012	0.924
PS3	←	Partner selection	1.549	0.404	3.837	***	0.546
PS4	←	Partner selection	0.055	0.268	0.205	0.838	0.016
TP1	←	Transfer process	1.000				0.728

(continued)

Table 110.2 (continued)

			Non-standardized	S.E.	C.R.	P	Standardized
TP3	←	Transfer process	0.760	0.106	7.157	***	0.600
TP4	←	Transfer process	0.790	0.095	8.320	***	0.736
TP5	←	Transfer process	0.629	0.100	6.314	***	0.522
TR1	←	Transfer risk	1.000				0.674
TR2	←	Transfer risk	0.812	0.130	6.233	***	0.510
TR3	←	Transfer risk	1.390	0.154	9.034	***	0.834
TR4	←	Transfer risk	−0.417	0.113	−3.683	***	−0.292
TR5	←	Transfer risk	1.153	0.134	8.611	***	0.748
Knowledge tranfer	←	Transfer motivation	1.000				0.207
Knowledge tranfer	←	Partner selection	1.000				0.208
Knowledge tranfer	←	Transfer effect	1.000				0.440
Knowledge tranfer	←	Transfer process	1.000				0.482
Knowledge tranfer	←	Transfer risk	1.000				0.396
TP6	←	Transfer process	0.764	0.103	7.391	***	0.623
TR6	←	Transfer risk	0.817	0.143	5.730	***	0.465

is closely related to the results of the research and development. Another additional path is the path between e25 and e26. The same situation goes for e29 and e31. The modified model and the path coefficient figure are presented as Figs. 110.6 and 110.7. Through two modifications, we obtained the optimal model.

The regression weights and variances are shown in Tables 110.8 and 110.9.

The fitting degree of the revision model (4) has to be evaluated as Table 110.10.

110.4 Model Explanations

The direct effect and indirect effect and total effect among the latent variables are presented as Table 110.11. The direct effect is the influence of reason variables on outcome variables, and can be reflected as path coefficients. The indirect effect is the influence of reason variables on outcome variables through multiple intermediate

Table 110.3 Results of the variance estimation

	Variance estimation	S.E.	C.R.	P		Variance estimation	S.E.	C.R.	P
z1	0.136	0.072	1.889	0.059	e23	0.905	0.095	9.570	***
z2	0.137	0.077	1.791	0.073	e24	0.307	0.067	4.584	***
z3	0.737	0.142	5.210	***	e25	1.368	0.161	8.476	***
z6	0.614	0.111	5.531	***	e26	0.638	0.113	5.647	***
z4	0.496	0.101	4.906	***	e7	1.237	0.134	9.261	***
z5	0.050	0.036	1.404	0.160	e8	0.275	0.550	0.500	0.617
z7	1.000				e9	0.777	0.138	5.641	***
e1	1.342	0.140	9.571	***	e10	1.667	0.168	9.899	***
e2	1.391	0.154	9.022	***	e12	0.653	0.095	6.878	***
e3	1.206	0.131	9.218	***	e14	0.756	0.090	8.423	***
e4	0.520	0.093	5.625	***	e15	0.390	0.058	6.742	***
e5	0.681	0.103	6.616	***	e16	0.777	0.087	8.926	***
e6	1.095	0.125	8.786	***	e17	0.596	0.073	8.178	***
e28	0.481	0.069	6.928	***	e18	0.932	0.101	9.202	***
e29	1.699	0.175	9.722	***	e19	0.420	0.081	5.206	***
e30	0.614	0.088	7.011	***	e20	0.923	0.095	9.717	***
e31	0.645	0.084	7.705	***	e21	0.520	0.073	7.164	***
e32	0.620	0.080	7.786	***	e33	0.678	0.082	8.229	***
e22	0.984	0.101	9.781	***	e11	1.202	0.128	9.354	***

Table 110.4 Results of the fit indices

Fit index	χ^2/dx^2	CFI	NFI	IFI	AIC	RMR	RMSEA
Results	4.438	0.774	0.734	0.780	2050.315	0.213	0.153

variables, and can be reflected as the product of path coefficients. The total effect is the sum of the direct effect and indirect effect. Model evaluation should be based on the optimal model path coefficients of Table 110.8.

110.4.1 The Effect of Transfer Motivation on Knowledge Transfer

For variables of Transfer Motivation, when the weighting coefficient of TM1 is 1, its standard coefficient is 0.528, and the weighting coefficients of TM2, TM3, TM4, TM5 and TM6 are 0.280, 0.643, 0.435, 0.297 and 0.682, CR is greater than 3, significant at

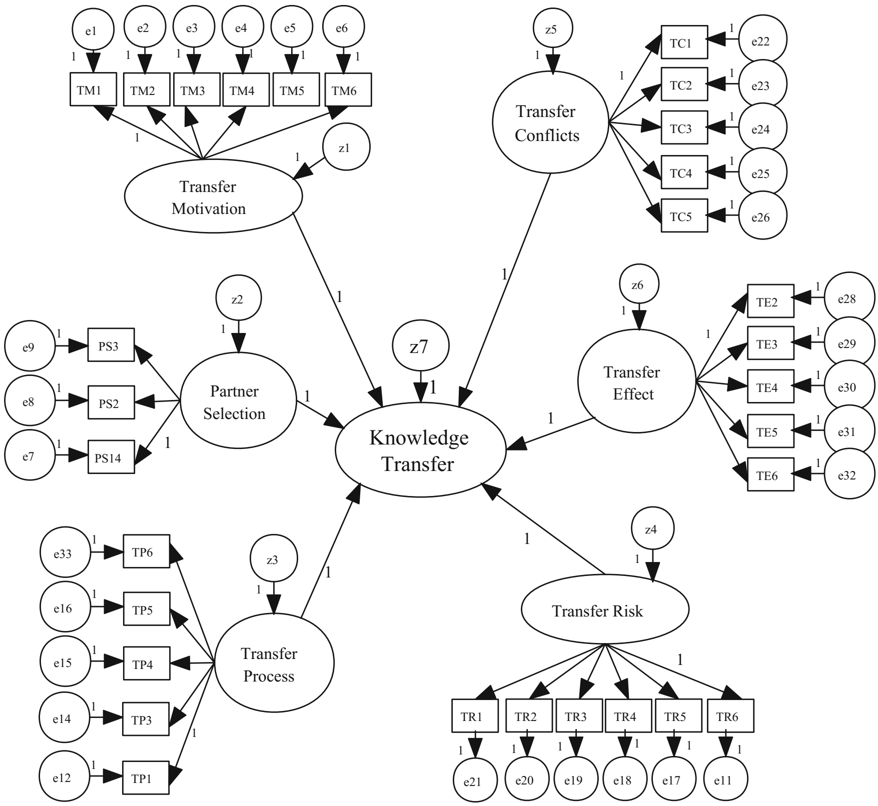


Fig. 110.4 Revision model (1)

5 % level, indicating the effectiveness and development of Transfer Motivation can be reflected by these indices.

The standardized path coefficients of Transfer Motivation to Knowledge Transfer is 0.185, indicating that the direct effect of Transfer Motivation to Knowledge Transfer is 0.185, namely for each 1 unit increases in the latent variable of Transfer Motivation, the latent variable of Knowledge Transfer increases 0.423 units.

Besides, there is an indirect effect of Transfer Motivation to Knowledge Transfer. The path is: Transfer Motivation → Partner Selection → Knowledge Transfer. Obviously, because of the intermediate variable, the indirect effect equals to the product of the two path coefficients. The direct effect of Transfer Motivation on Partner Selection is 0.749, and the direct effect of Partner Selection on Knowledge Transfer is 0.112. Thus, the indirect effect of Transfer Motivation to Knowledge Transfer is 0.084. The total effect of Transfer Motivation to Knowledge Transfer is 0.269.

The standardized path coefficients of Transfer Motivation to Partner Selection is 0.749, indicating that the direct effect of Transfer Motivation on Partner Selection is 0.749, namely for each 1 unit increases in the latent variable of Transfer Motivation, the latent variable of Partner Selection increases 0.424 units.

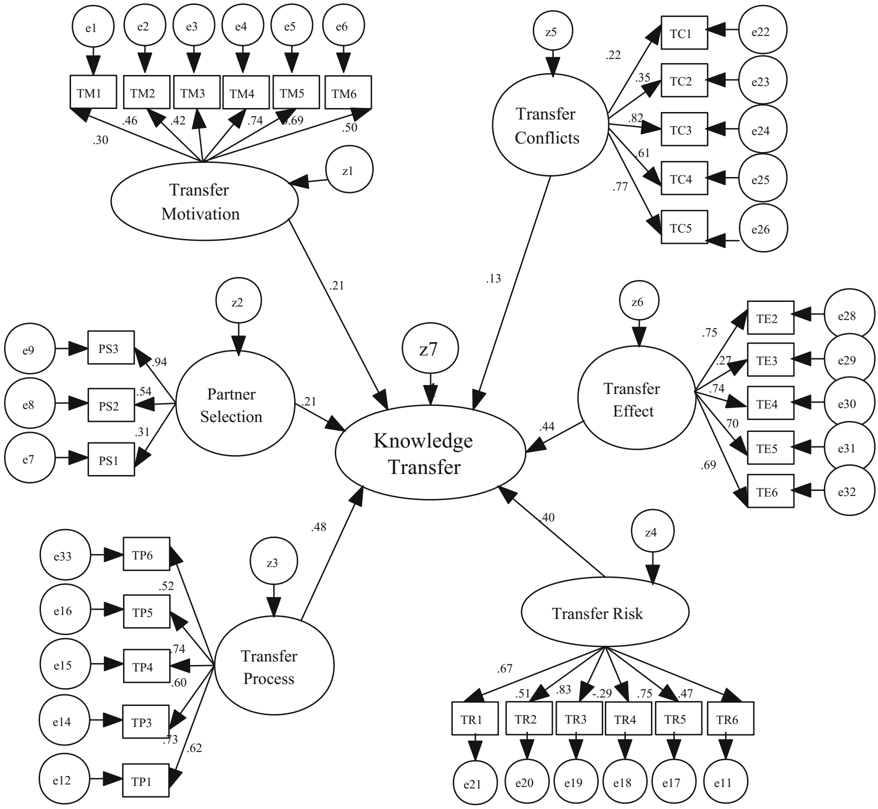


Fig. 110.5 Standardized parameter estimation result of revision model (1)

110.4.2 The Effect of Partner Selection on Knowledge Transfer

For variables of Partner Selection, when the weighting coefficient of PS1 is 1, its standard coefficient is 0.331, and the weighting coefficients of PS2 and PS3 are 0.678 and 0.734, CR is greater than 3, significant at 5 % level, indicating the effectiveness and development of Partner Selection can be reflected by these indices.

The standardized path coefficients of Partner Selection to Knowledge Transfer is 0.112, indicating that the direct effect of Partner Selection on Knowledge Transfer is 0.112, namely for each 1 unit increases in the latent variable of Transfer Motivation, the latent variable of Knowledge Transfer increases 0.423 units.

Table 110.5 Results of the coeff. estim. of revision model (1)

			Non-standardized	S.E.	C.R.	P	Standardized
TM1	←	Transfer motivation	1.000				0.304
TM2	←	Transfer motivation	1.652	0.507	3.257	0.001	0.459
TM3	←	Transfer motivation	1.359	0.432	3.142	0.002	0.416
TM4	←	Transfer motivation	2.181	0.603	3.616	***	0.745
TM5	←	Transfer motivation	2.156	0.600	3.595	***	0.694
TM6	←	Transfer motivation	1.645	0.491	3.350	***	0.502
TE2	←	Transfer effect	1.000				0.749
TE3	←	Transfer effect	0.470	0.137	3.436	***	0.272
TE4	←	Transfer effect	1.114	0.123	9.032	***	0.744
TE5	←	Transfer effect	0.999	0.116	8.604	***	0.698
TE6	←	Transfer effect	0.962	0.113	8.537	***	0.692
TC1	←	Transfer conflict	1.000				0.220
TC2	←	Transfer conflict	1.592	0.656	2.427	0.015	0.351
TC3	←	Transfer conflict	3.508	1.265	2.772	0.006	0.817
TC4	←	Transfer conflict	3.974	1.466	2.712	0.007	0.605
TC5	←	Transfer conflict	4.370	1.577	2.771	0.006	0.774
PS1	←	Partner selection	1.000				0.313
PS2	←	Partner selection	3.491	1.415	2.467	0.014	0.936
PS3	←	Partner selection	1.543	0.402	3.838	***	0.539
TP1	←	Transfer process	1.000				0.728
TP3	←	Transfer process	0.760	0.106	7.157	***	0.600
TP4	←	Transfer process	0.790	0.095	8.320	***	0.736
TP5	←	Transfer process	0.629	0.100	6.314	***	0.522
TR1	←	Transfer risk	1.000				0.674

(continued)

Table 110.5 (continued)

			Non-standardized	S.E.	C.R.	P	Standardized
TR2	←	Transfer risk	0.812	0.130	6.233	***	0.510
TR3	←	Transfer risk	1.390	0.154	9.034	***	0.834
TR4	←	Transfer risk	−0.417	0.113	−3.683	***	−0.292
TR5	←	Transfer risk	1.153	0.134	8.611	***	0.748
Knowledge tranfer	←	Transfer motivation	1.000				0.207
Knowledge tranfer	←	Partner Selection	1.000				0.206
Knowledge tranfer	←	Transfer conflict	1.000				0.126
Knowledge tranfer	←	Transfer effect	1.000				0.440
Knowledge tranfer	←	Transfer Process	1.000				0.482
Knowledge tranfer	←	Transfer Risk	1.000				0.396
TP6	←	Transfer process	0.764	0.103	7.391	***	0.623
TR6	←	Transfer risk	0.817	0.143	5.730	***	0.465

110.4.3 The Effect of Transfer Process on Knowledge Transfer

For variables of Transfer Process, when the weighting coefficient of TM1 is 1, its standard coefficient is 0.657, and the weighting coefficients of TP3, TP4, TP5 and TP6 are 0.625, 0.735, 0.504 and 0.680, CR is greater than 3, significant at 5 % level, indicating the effectiveness and development of Transfer Process can be reflected by these indices.

The standardized path coefficients of Transfer Process to Knowledge Transfer is 0.223, indicating that the direct effect of Transfer Process on Knowledge Transfer is 0.223, namely for each 1 unit increases in the latent variable of Transfer Process, the latent variable of Knowledge Transfer increases 0.223 units.

There is an indirect effect of Transfer Process to Transfer Motivation, the path is: Transfer Process → Transfer Risk → Transfer Motivation. The indirect effect equals to the product of the two path coefficients. The direct effect of Transfer Process on Transfer Risk is 1.027, and the direct effect of Transfer Risk on Transfer Motivation is 0.786. Thus, the indirect effect of Transfer Process to Transfer Motivation is 0.807; there is an indirect effect of Transfer Process to Partner Selection, the path is: Transfer Process → Transfer Risk → Partner Selection. The indirect effect of Transfer Process to Partner Selection is 0.605; The path of an indirect effect of Transfer Process to

Table 110.6 Results of the variance estimation of revision model (1)

	Variance estimation	S.E.	C.R.	P		Variance estimation	S.E.	C.R.	P
z1	0.136	0.072	1.889	0.059	e23	0.905	0.095	9.570	***
z2	0.137	0.077	1.791	0.073	e24	0.307	0.067	4.584	***
z3	0.737	0.142	5.210	***	e25	1.368	0.161	8.476	***
z6	0.614	0.111	5.531	***	e26	0.638	0.113	5.647	***
z4	0.496	0.101	4.906	***	e7	1.240	0.134	9.260	***
z5	0.050	0.036	1.404	0.160	e8	0.233	0.577	0.404	0.686
z7	1.000				e9	0.786	0.138	5.699	***
e1	1.342	0.140	9.571	***	e12	0.653	0.095	6.878	***
e2	1.391	0.154	9.022	***	e14	0.756	0.090	8.423	***
e3	1.206	0.131	9.218	***	e15	0.390	0.058	6.742	***
e4	0.520	0.093	5.625	***	e16	0.777	0.087	8.926	***
e5	0.681	0.103	6.616	***	e17	0.596	0.073	8.178	***
e6	1.095	0.125	8.786	***	e18	0.932	0.101	9.202	***
e28	0.481	0.069	6.928	***	e19	0.420	0.081	5.206	***
e29	1.699	0.175	9.722	***	e20	0.923	0.095	9.717	***
e30	0.614	0.088	7.011	***	e21	0.520	0.073	7.164	***
e31	0.645	0.084	7.705	***	e33	0.678	0.082	8.229	***
e32	0.620	0.080	7.786	***	e11	1.202	0.128	9.354	***
e22	0.984	0.101	9.781	***					

Table 110.7 Results of the fit indices

Fit index	χ^2/dx^2	CFI	NFI	IFI	AIC	RMR	RMSEA
Results	4.385	0.776	0.735	0.781	1896.245	0.215	0.154

Transfer Conflict is: Transfer Process → Transfer Risk → Transfer Conflict. The indirect effect of Transfer Process to Transfer Conflict is 0.876; The path of an indirect effect of Transfer Process to Transfer Effect is: Transfer Process → Transfer Risk → Transfer Effect. The indirect effect of Transfer Process to Transfer Effect is 0.798.

Besides, there is an indirect effect of Transfer Process to Knowledge Transfer. It concludes: Transfer Process → Transfer Risk → Knowledge Transfer; Transfer Process → Transfer Risk → Transfer Motivation → Knowledge Transfer; Transfer Process → Transfer Risk → Partner Selection → Knowledge Transfer; Transfer Process → Transfer Risk → Transfer Conflict → Knowledge Transfer; Transfer Process → Transfer Risk → Transfer Effect → Knowledge Transfer. Its coefficient is: $1.207 \times 0.216 + 0.807 \times 0.185 + 0.605 \times 0.112 + 0.876 \times 0.106 +$

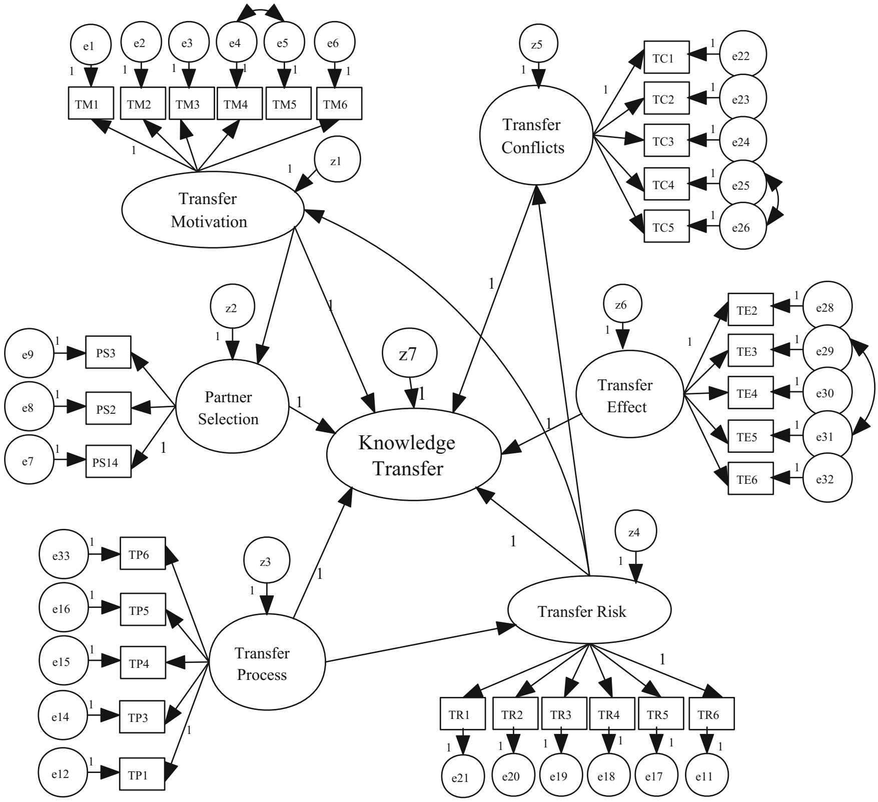


Fig. 110.6 Revision model (4)

$0.798 \times 0.234 = 0.718$. Thus, the total effect of Transfer Process to Knowledge Transfer is 0.941.

110.4.4 The Effect of Transfer Risk on Knowledge Transfer

For variables of Transfer Risk, when the weighting coefficient of TR1 is 1, its standard coefficient is 0.719, and the weighting coefficients of TR2, TR3, TR4, TR5 and TR6 are 0.479, 0.749, −0.211, 0.758 and 0.521, CR is greater than 3, significant at 5 % level, indicating the effectiveness and development of Transfer Risk can be reflected by these indices.

The standardized path coefficients of Transfer Risk to Knowledge Transfer is 0.216, indicating that the direct effect of Transfer Process on Knowledge Transfer is 0.216, namely for each 1 unit increases in the latent variable of Transfer Risk, the latent variable of Knowledge Transfer increases 0.223 units. Similarly, the standard-

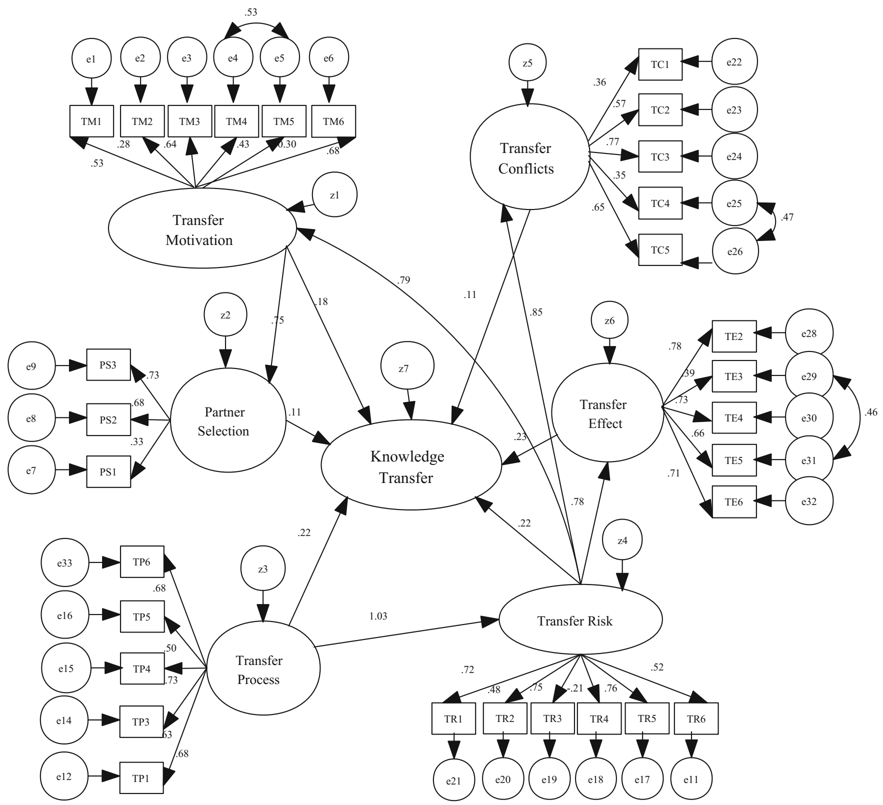


Fig. 110.7 Standardized parameter estimation result of revision model (4)

ized path coefficients of Transfer Risk to Transfer Motivation is 0.786, indicating that the direct effect of Transfer Risk on Transfer Motivation is 0.786; the standardized path coefficients of Transfer Risk to Transfer Conflict is 0.853, indicating that the direct effect of Transfer Risk on Transfer Conflict is 0.853; the standardized path coefficients of Transfer Risk to Transfer Effect is 0.778, indicating that the direct effect of Transfer Risk on Transfer Effect is 0.778.

There is an indirect effect of Transfer Risk to Partner Selection, the path is: Transfer Risk → Transfer Motivation → Partner Selection. The direct effect of Transfer Risk on Transfer Motivation is 0.786, and the direct effect of Transfer Motivation on Partner Selection is 0.749. Thus, the indirect effect of Transfer Risk to Partner Selection is 0.589.

Besides, there is an indirect effect of Transfer Risk to Knowledge Transfer. It concludes: Transfer Risk → Transfer Motivation → Knowledge Transfer; Transfer Risk → Transfer Motivation → Partner Selection → Knowledge Transfer; Transfer Risk → Transfer Conflict → Knowledge Transfer; Transfer Risk → Transfer Effect → Knowledge Transfer. Its coefficient is: $0.786 \times 0.185 + 0.589 \times 0.112 +$

Table 110.8 Results of the coeff. estim. of revision model (4)

			Non-standardized	S.E.	C.R.	P	Standardized
Transfer risk	←	Transfer process	0.995	0.113	8.793	***	1.027
Transfer motivation	←	transfer Risk	0.672	0.110	6.131	***	0.786
Transfer effect	←	Transfer risk	0.841	0.099	8.489	***	0.778
Transfer conflict	←	Transfer risk	0.420	0.093	4.518	***	0.853
Partner selection	←	Transfer motivation	0.453	0.130	3.477	***	0.749
TM1	←	Transfer motivation	1.000				0.528
TM2	←	Transfer motivation	0.580	0.175	3.305	***	0.280
TM3	←	Transfer motivation	1.208	0.198	6.106	***	0.643
TM4	←	Transfer motivation	0.732	0.155	4.729	***	0.435
TM5	←	Transfer motivation	0.529	0.153	3.460	***	0.297
TM6	←	Transfer motivation	1.284	0.204	6.296	***	0.682
TE2	←	Transfer effect	1.000				0.777
TE3	←	Transfer effect	0.316	0.103	3.068	***	0.190
TE4	←	Transfer effect	1.056	0.107	9.882	***	0.732
TE5	←	Transfer effect	0.911	0.103	8.866	***	0.660
TE6	←	Transfer effect	0.958	0.099	9.648	***	0.715
TC1	←	Transfer conflict	1.000				0.364
TC2	←	Transfer conflict	1.561	0.364	4.292	***	0.568
TC3	←	Transfer conflict	2.004	0.430	4.661	***	0.771
TC4	←	Transfer conflict	1.386	0.409	3.391	***	0.349
TC5	←	Transfer conflict	2.219	0.496	4.478	***	0.650

(continued)

Table 110.8 (continued)

			Non-standardized	S.E.	C.R.	P	Standardized
PS1	←	Partner selection	1.000				0.331
PS2	←	Partner selection	2.392	0.621	3.850	***	0.678
PS3	←	Partner selection	1.987	0.513	3.877	***	0.734
TP1	←	Transfer process	1.000				0.657
TP3	←	Transfer process	0.876	0.109	8.005	***	0.625
TP4	←	Transfer process	0.874	0.095	9.210	***	0.735
TP5	←	Transfer process	0.671	0.102	6.581	***	0.504
TR1	←	Transfer risk	1.000				0.719
TR2	←	Transfer risk	0.716	0.110	6.486	***	0.479
TR3	←	Transfer risk	1.171	0.115	10.198	***	0.749
TR4	←	Transfer risk	−0.282	0.089	−3.169	***	−0.211
TR5	←	Transfer risk	1.096	0.106	10.324	***	0.758
Knowledge tranfer	←	Transfer motivation	1.000				0.185
Knowledge tranfer	←	Partner selection	1.000				0.112
Knowledge tranfer	←	Transfer conflict	1.000				0.106
Knowledge tranfer	←	Transfer effect	1.000				0.234
Knowledge tranfer	←	Transfer process	1.000				0.223
Knowledge tranfer	←	Transfer risk	1.000				0.216
TP6	←	Transfer Process	0.923	0.107	8.614	***	0.680
TR6	←	Transfer Risk	0.859	0.122	7.058	***	0.521

Table 110.9 Results of the variance estimation of revision model (4)

	Variance estimation	S.E.	C.R.	P		Variance estimation	S.E.	C.R.	P
z1	0.157	0.049	3.204	***	e23	0.698	0.079	8.896	***
z2	0.137	0.033	4.125	***	e24	0.374	0.057	6.551	***
z3	0.601	0.119	5.044	***	e25	1.896	0.198	9.573	***
z6	0.261	0.054	4.825	***	e26	0.920	0.110	8.331	***
z4	−0.030	0.007	−4.285	***	e7	1.224	0.129	9.478	***
z5	0.037	0.011	3.364	***	e8	1.012	0.151	6.721	***
z7	1.000				e9	0.511	0.091	5.595	***
e1	1.066	0.119	8.978	***	e12	0.789	0.085	9.308	***
e2	1.625	0.167	9.699	***	e14	0.720	0.076	9.421	***
e3	0.855	0.104	8.204	***	e15	0.391	0.044	8.870	***
e4	0.948	0.101	9.347	***	e16	0.797	0.082	9.671	***
e5	1.199	0.124	9.665	***	e17	0.527	0.058	9.026	***
e6	0.784	0.101	7.797	***	e18	0.970	0.100	9.660	***
e28	0.434	0.060	7.217	***	e19	0.605	0.068	8.851	***
e29	1.769	0.180	9.826	***	e20	0.964	0.098	9.862	***
e30	1.769	0.180	9.826	***	e21	0.501	0.057	8.789	***
e31	0.710	0.083	8.542	***	e33	0.597	0.065	9.212	***
e32	0.581	0.072	8.068	***	e11	1.117	0.116	9.600	***
e22	0.898	0.094	9.586	***					

Table 110.10 Results of fit indices of revision model (4)

Fit index	χ^2/dx^2	CFI	NFI	IFI	AIC	RMR	RMSEA
Results	2.743	0.957	0.942	0.963	1425.150	0.078	0.056

$0.853 \times 0.106 + 0.778 \times 0.234 = 0.484$. Thus, the total effect of Transfer Process to Knowledge Transfer is 0.700.

110.4.5 The Effect of Transfer Conflict on Knowledge Transfer

For variables of Transfer Conflict, when the weighting coefficient of TR1 is 1, its standard coefficient is 0.364, and the weighting coefficients of TC2, TC3, TC4 and TC5 are 0.568, 0.771, 0.349 and 0.650, CR is greater than 3, significant at 5 % level,

Table 110.11 Direct, indirect and total effects of latent variables

	Transfer process	Transfer risk	Transfer motivation	Partner selection	Transfer conflict	Transfer effect
Transfer risk	1.027					
	1.027					
Transfer motivation		0.786				
	0.807					
	0.807	0.786				
Partner selection			0.749			
	0.605	0.589				
	0.605	0.589	0.749			
Transfer conflict		0.853				
	0.876					
	0.876	0.853				
Transfer effect		0.778				
	0.798					
	0.798	0.778				
Knowledge transfer	0.223	0.216	0.185	0.112	0.106	0.234
	0.718	0.484	0.084			
	0.941	0.700	0.269	0.112	0.106	0.234

indicating the effectiveness and development of Transfer Conflict can be reflected by these indices.

The standardized path coefficients of Transfer Conflict to Knowledge Transfer is 0.106, indicating that the direct effect of Transfer Conflict on Knowledge Transfer is 0.106, namely for each 1 unit increases in the latent variable of Transfer Conflict, the latent variable of Knowledge Transfer increases 0.106 units.

110.4.6 The Effect of Transfer Effect on Knowledge Transfer

For variables of Transfer Effect, when the weighting coefficient of TE2 is 1, its standard coefficient is 0.777, and the weighting coefficients of TE3, TE4 TE5 and TE6 are 0.190, 0.732, 0.660 and 0.715, CR is greater than 3, significant at 5 % level, indicating the effectiveness and development of Transfer Effect can be reflected by these indices.

The standardized path coefficients of Transfer Effect to Knowledge Transfer is 0.234, indicating that the direct effect of Transfer Effect on Knowledge Transfer is 0.234, namely for each 1 unit increases in the latent variable of Transfer Effect, the latent variable of Knowledge Transfer increases 0.234 units.

110.4.7 Summary

In our empirical analysis, we focused on the analysis of the six major shift factors on knowledge transfer. From the results, we can see that the six factors have different degrees impact on knowledge transfer. Influence coefficients are: TP-0.941, TR-0.700, TM-0.269, TE-0.234, PS-0.112 and TC-0.106. Percentage are: 39.84, 29.64, 11.38, 9.91, 4.74 and 4.49 %.

Transfer process has the greatest impact on knowledge transfer, not only has a direct impact, but also an indirect impact. This is because the transfer process of knowledge transfer and absorption is to achieve effective application of knowledge and creativity. Transfer risk has a greater impact on knowledge transfer, not only has a direct impact, but also an indirect impact. This is because that Knowledge transfer is to achieve the prerequisite and basis of knowledge innovation, however, the inherent characteristics of knowledge increases the risk of knowledge transfer process, which has become an indisputable fact.

110.5 Conclusions and Discussion

The objective of this paper has been to explore the factors affecting the relative importance of knowledge transfer between university and industry. Combined with the multivariate statistical analysis, we have screed out 6 factors including transfer motivation, partner selection, transfer process, transfer risk, transfer conflict and transfer effect. When the early influence indicators are finalized, the selected indicators are being analysed thoroughly. In order to further analyse the factors that influence the degree of knowledge transfer, a structural equation may be established to test the influence degree by means of selecting indicators. Then we calculate the value of six first-level indicators and give subjective weights to the indicators by AMOS 7.0. Through several adjustments, optimal structural equation model is established. Further, we analysed the influence degree of all the affecting factors on knowledge transfer between university and industry. This approach provides a new perspective for scientific and technological evaluation in general sense. It should be noted that the availability of basic data and the rationality of modeling bear much upon the evaluation results. To undertake this purpose, this paper used data collected from two questionnaires, one addressing China industrial researchers and the other addressing China university researchers. Our evidence shows that impact indicators on knowledge transfer in the order are: transfer process, transfer risk, transfer motivation, transfer effect, partner selection and transfer conflict.

Moreover, our findings have a number of implications for policy makers, both at the national and international level. For knowledge transfer both sides, we have the following suggestions: Creating an effective knowledge-based knowledge transfer channel characteristics, in order to reduce the adverse effects of the transfer process; Building an effective communication system and risk-sharing mechanisms to reduce the risk of impact on knowledge transfer; Establishing incentive mechanisms to make the sender has been to maximize the contribution of knowledge.

In this paper, structural equation modelling can be used to analyse and evaluate various factors on knowledge transfer. For structural equation modelling, if the data is inaccurate or wrong, no satisfactory results will be got, which is the so-called "garbage in and garbage out". In scientific and technological evaluation, some data is very difficult to be obtained sometimes. People may only find data for a limited number of indicators, which cannot reflect the whole picture of certain element. In such circumstances, none of the evaluation approaches will get satisfactory evaluation result. The evaluation using structural equation modeling is no exception. In this case, the combination of peer review may improve the effectiveness and accuracy of evaluation. On the other hand, structural equation is essentially a method combining the objective and subjective evaluation approaches. The relationship among variables is defined subjectively, or for the relationships among those indicators impact people's subjective will are always involved. Any improperly set relationship among the elements of the structural equation, which is due to human incomplete understanding or misunderstanding of the inherent relationship among elements, is possible to lead to the calculation error and the evaluation results will be biased. To solve this problem, it is better to absorb the views of different experts when adopting structural equation modelling.

Acknowledgments The research was supported by The soft science project of Science and Technology Department of Sichuan Province (2014ZR0016), P.R. China; College of Humanities and social science research base in Sichuan Province: "key task of Systems Science and Enterprise Development Research Center."(Xq14B06); The young and middle-aged leader scientific research foundation of Chengdu University of Information Technology (J201218), People's Republic of China; Bringing in qualified personnel projects of Chengdu University of Information Technology (KYTZ201203), People's Republic of China.

References

1. Balconi M, Laboranti A (2006) University-industry interactions in applied research: the case of microelectronics. Res Policy 35(10):1616–1630
2. Beise M, Stahl H (1999) Public research and industrial innovations in Germany. Res Policy 28(4):397–422
3. Cohen WM, Levinthal DA (1990) Absorptive capacity: a new perspective on learning and innovation. Adm Sci Q 35:128–152

4. Cohen WM, Nelson RR, Walsh JP (2002) Links and impacts: the influence of public research on industrial R&D. Manag Sci 48(1):1–23
5. Gübeli MH, Doloreux D (2005) An empirical study of university spin-off development. Eur J Innov Manag 8(3):269–282
6. Kingsley G, Bozeman B, Coker K (1996) Technology transfer and absorption: an 'R&D value-mapping' approach to evaluation. Res Policy 25(6):967–995
7. Mansfield E (1991) Academic research and industrial innovation. Res Policy 20(1):1–12
8. Mansfield E (1998) Academic research and industrial innovation: an update of empirical findings. Res Policy 26(7):773–776
9. Martinelli A, Meyer M, Von Tunzelmann N (2008) Becoming an entrepreneurial university? A case study of knowledge exchange relationships and faculty attitudes in a medium-sized, research-oriented university. J Technol Transf 33(3):259–283
10. McMillan GS, Narin F, Deeds DL (2000) An analysis of the critical role of public science in innovation: the case of biotechnology. Res Policy 29(1):1–8
11. Monjon S, Waelbroeck P (2003) Assessing spillovers from universities to firms: evidence from french firm-level data. Int J Ind Organ 21(9):1255–1270
12. Narin F, Hamilton KS, Olivastro D (1997) The increasing linkage between us technology and public science. Res Policy 26(3):317–330
13. Salter AJ, Martin BR (2001) The economic benefits of publicly funded basic research: a critical review. Res Policy 30(3):509–532
14. Santoro MD, Gopalakrishnan S (2001) Relationship dynamics between university research centers and industrial firms: their impact on technology transfer activities. J Technol Transf 26(1–2):163–171
15. Siegel DS, Waldman DA et al (2004) Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies. J Eng Technol Manag 21(1):115–142

Chapter 111
Discrete Time-Cost-Environment Trade-Off Problem and Its Application to a Large-Scale Construction Project

Huan Zheng and Lin Zhong

Abstract This paper presents a discrete time-cost-environment trade-off problem (DTCETP) by a hybrid genetic algorithm, to a large-scale construction project in the southwest region of China. The objective functions in this paper are to minimize the total project time, to minimize the total penalty cost, and to minimize environmental impact. After describing the problem of the working procedure in the project, it gives the mathematical formulation model of a DTCETP. Furthermore, because traditional optimization techniques could not cope with the DTCETP effectively, we present a new approach based on the hybrid genetic algorithm (hGA). A hybrid genetic algorithm is developed for finding feasible solutions. Finally, a large scale construction projects is used as a practical example to demonstrate the practicality and efficiency of the model. Results and sensitivity analysis are presented to highlight the performances of the optimization method, which is very effective and efficient as compared to other algorithms. The computer generated results validate the effectiveness of the proposed model and algorithm in solving large-scale practical problems.

Keywords Time-cost-environment · Trade-off · Hybrid genetic algorithm

---

H. Zheng (✉)
College of Economics and Management, Southwest University,
Chongqing 400715, People's Republic of China
e-mail: 290871340@qq.com

H. Zheng
Chongqing Business Administration Research Center, Chongqing 400067,
People's Republic of China

L. Zhong
Uncertainty Decision-Making Laboratory, Sichuan University, Chengdu 610065,
People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_111

111.1 Introduction

This paper focuses on the discrete time-cost-environment trade-off problem (DTCETP) in large-scale construction projects for minimizing the total project cost, project duration, and environmental impact. The discrete time-cost trade-off problem (DTCTP), which was introduced by Harvey and Patterson [8], is an important subject in the project trade-off problem. Recently, construction project has been accused of causing environmental problems ranging from excessive consumption of global resources both in terms of construction and operation to the pollution of the surroundings [1]. In particular, constriction project is regarded as one of the most critical factors contributing to changing environment [2], in which eco-environmental impact may arise during all project phases [1]. As such, in expedition of a construction project, its environmental impact should be taken into consideration along with the time and cost trade-offs [10–13, 17, 19]. Therefore, this paper considers that construction managers need to develop a project management decision for controlling the total project duration, project penalty costs, and environmental impact in a construction projects in order to achieve management objectives.

111.2 Problem Description and Mathematical Formulation Model

111.2.1 Assumptions

To model the time-cost-environment trade-off for large-scale projects in this paper, assumptions are as follows:

(1) The DTCETP consists of a number of activities.
(2) The starting time of each activity is dependent upon the completion of its predecessor.
(3) Capital used by all activities does not exceed limited quantities in any time period, and the total project budget is within deterministic limit.
(4) The environmental impact caused by activities does not exceed limited quantities in any time period, and the total project environmental impact is within deterministic limit.
(5) When an activity is beginning, it cannot be interrupted.
(6) The managerial objective is to minimize the total project time, the total tardiness penalty and the total environmental impact for all projects.

111.2.2 Model Formulation

The problem is represented on an activity-on-node (AON) network with a single starting and a single ending node both corresponding to dummy activities.

$\tilde{d}_j$: the processing time of activity j
l_{jc}: the cost of activity j for unit time
l_{je}: the environmental impact of activity j for unit time
c^p: the total penalty cost for unit time
b_c: the maximum-limit cost only available for unit time of sub-project
b_e: the maximum-limit environmental impact only available for unit time of sub-project
B_c: the maximum-limit environmental impact only available for unit time of project
B_e: the maximum-limit environmental impact only available for unit time of sub-project
$\tilde{t}_j^f$: the finish time of activity j
V_j: the environmental impact of activity j
w_j: the weight of activity j for environmental impact
S_p: the set of activities being in progress in period p
$S_p = \left\{ j \left| t_j^S \le p \le t_j^S + t_j, j = 1, 2, \cdots, J + 1 \right. \right\}$
$\Pr e(j)$: set of the immediate predecessors of Activity j
$\tilde{t}_j^S$: the start time of activity j
z_1: the total duration for the project
z_2: the total penalty cost for the project
z_3: the total environmental impact for the project

111.2.3 Multi-objective Model

Based on the requirement of the manager's objectives for the project, an optimization model is proposed to solve it. The following subsections in this paper explain the multi-objective model in details with objectives and constraints separately in order to illustrate the model more clearly.

(1) Objective Functions

The first objective seeks to minimize the total project time, that is the sum of the completion time for all activities. It can be described as follows:

$$\min z_1 = \sum_{j=1}^{J} \tilde{t}_j^F. \tag{111.1}$$

Furthermore, the second objective is to measure and minimize the total cost. We minimize the total penalty of multiple projects, we develop a mathematical formulation of the objective as follows:

$$\min z_2 = \sum_{j=1}^{J} c^p(\tilde{t}_j^F - \tilde{t}_j^D). \tag{111.2}$$

Finally, the third objective is to minimize the total environmental impact.

$$\min z_3 \frac{\sum_{j=1}^{J} V_j \times w_j(\tilde{t}_j^F - \tilde{t}_j^D)}{\tilde{t}_j^F}. \tag{111.3}$$

(2) Constraints

The start time of each activity is dependent upon the completion of some other activities (precedence constraints of activities). After finishing a specific activity, the next activity must be also started in a project, therefore, we use the constraint:

$$E(\tilde{t}_l^S) \le E(\tilde{t}_j^S) - E(\tilde{d}_l), \quad l \in \Pr e(j). \tag{111.4}$$

It is also basic and important for project to limit the total capital and the capital in per time period used by the project.

$$\sum_{j \in S_p} l_{jc} \le B_c. \tag{111.5}$$

It is also important for project to limit the total environmental impact and the environmental impact in per time period caused by the project.

$$\sum_{j \in S_p} l_{je} \times w_j \le B_e, \quad l_{je} = \frac{V_j}{d_j}. \tag{111.6}$$

111.3 Hybrid Genetic Algorithm

For the multi-objective model formulated above, it is possible to find several Pareto optimal solutions for the problem. However, in construction project practice, only exact one optimized solution could conduct the decision making in pressing situation. Thus, the weighting method is applied to transform the multi-objective model into a single-objective one. Determination of the GA parameters is a very important factor, especially when solving large scale problems.

111.3.1 Overall Procedure of the Proposed Method

The hybrid genetic algorithm for solving the problem is presented as follows.

Step 1. The weight-sum procedure is used to concentrate multiple objectives.
Step 2. Set the parameters of the genetic algorithm: population size, the crossover rate the mutation rate, and the maximum generation.
Step 3. Initialization: Generate an initial set of individuals.
Step 4. Selection and hybrid genetic operators: crossover and mutation.
Step 5. Evaluation the fitness value.
Step 6. Select the best total penalty of the minimized total project time and store the alternative schedule with the minimized total project time.
Step 7. Termination checking: If one of the individuals achieves the pre-defined fitness value, then stop; otherwise, go to step 8.
Step 8. Regulating of the mutation rate adaptively, then go back to step 4.

111.3.2 Representation

To initialize the hybrid genetic algorithm, we describe the serial method-based priority rule [9]. The position is used to denote an activity number, and the value of gene is used to represent the priority associated with the activity for constructing a schedule among candidates. The larger the integer, the higher the priority. The priority of each activity is used to create a feasible activity sequence that satisfies the precedence constraint in the model.

111.3.3 Hybrid Genetic Operators

(1) Crossover Operator

As a crossover operator, the position-based crossover is used. The position-based crossover essentially takes some genes from one parent at random and fills a vacuum position with genes from the other parent by scanning from left-to-right.

(2) Swap Mutation Operator

Here, the swap mutation (SM) operator, select two projects at random and swap their contents.

111.4 A Case Study

111.4.1 Presentation of Case Problem

A large-scale project example is analyzed in order to illustrate the use of the present optimization model and demonstrate its capabilities. Besides two dummy projects (start and end project), the procedure contains five activities, as shown in Fig. 111.1.

To optimize all aspects of the project, the decision makers want to pursue their management objectives through a better arrangement of the start time of each activity. The proposed model and method are used to assist the decision maker optimally schedule the construction activities. Each activity has certain maximal unit requirements of cost and environmental impact. The detailed corresponding data for each activity are shown in Table 111.1.

Based on the representation of the case problem, the proposed method can be used to establish the mathematical model.

Other relevant data are as follows: the maximum amount of capital (units: million RMB) and environmental impact is 14 and 10 units for each time period, $(B_c, B_e) = (14, 10)$. The penalty cost in each time period $c^p = 10$ (units: million RMB).

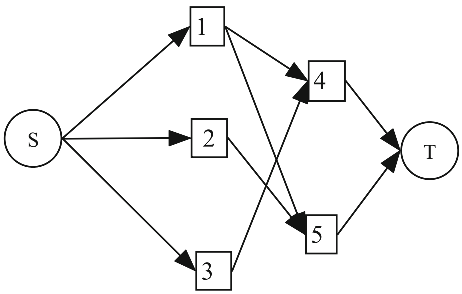


Fig. 111.1 Configuration of the construction project

Table 111.1 Detailed information of each activity

	DA	*C*	*EI* and *W*	*DP*	*PP*
S					
1	3	3	20.0, 0.05	11	$1 < 4, 5$
2	5	3	13.5, 0.037	11	$2 < 4, 5$
3	2	2	27.0, 0.037	11	$3 < 4, 5$
4	2	2	10.6, 0.047	11	$4 < T$
5	1	2	25.6, 0.039	10	$5 < T$
T					

Table 111.2 Optimal solution for the case study

The optimal schedule	$a1 : 0 - 0$; $a2 : 0 - 3$; $a3 : 3 - 6$; $a4 : 3 - 8$; $a5 : 8 - 10$
The sum of the completion times for all sub-project	10 (month)
Total penalty cost	-2 (million RMB)
Total environmental impact	-1.22
Fitness value	0.571

The related dates are the duration of an activity, cost, predecessor of activities, duration of the project and predecessor of the project. (Note: in Table 111.1, $DA =$ Expected value for Duration of activity (month), $C =$ Cost (million RMB), $PA =$ Predecessor of activities, $DP =$ Expected value for Activities, $PP =$ Predecessor of Activities), EI and $W =$ Environmental impact and Weight. Here,

111.4.2 Result of Case Problem

The circumstance of the computation for the problem is set as follows: based on the above model, the proposed flc-hGA, is programmed using Visual C++ language and run on a Pentium 4, 2.40 GHz clock pulse with 1024 MB memory. The detailed results are shown in Table 111.2.

The optimal Schedule for the case study is: $a1 : 0 - 0$; $a2 : 0 - 3$; $a3 : 3 - 6$; $a4 : 3 - 8$; $a5 : 8 - 10$.

Since our mathematical model is formulated with some assumptions, there may be some possible modeling errors. Thus, the results obtained above can not 100 % present an optimal time-cost-environment trade-off solution. However, to some extent, our results can provide decision makers with a theoretical optimal schedule for guiding current practice.

111.5 Conclusions

In this paper, a multiple objective trade-off problem for large-scale construction projects is proposed for dealing with project scheduling while minimizing the total project duration, project penalty cost, and the environmental impact. The main advantage of the proposed method is that it provides a systematic workable method for the decision-making process. In order to solve the problem, a hGA is developed to enhance the optimization quality and stability. Finally, a project is used as a practical example to demonstrate the practicality and efficiency of the model.

The area for future research has three aspects: firstly, investigate hybrid uncertainties, such as fuzzy or random systems to handle the model more reasonably and effectively. Secondly, more complex practical problems such as more dimensions scheduling should be considered. Thirdly, more efficient heuristic methods to solve these NP hard problems with more constraints could be developed. Each of these areas is very important and equally worthy of attention. A detailed analysis and further research are necessary to reveal more properties for solving these problems.

Acknowledgments This work was supported by the Project of the Key Research Base of Philosophy and Social Sciences in Sichuan Province (Xq15C12).

References

1. Brismar A (2004) Attention to impact pathways in EISs of large dam projects. Environ Impact Assess Rev 24(1):59–87
2. Chen S, Chen B, Su M (2011) The cumulative effects of dam project on river ecosystem based on multi-scale ecological network analysis. Proc Environ Sci 5:12–17
3. Demeulemeester E, Herroelen W (2002) Project scheduling: a research handbook. Kluwer Academic Publishers, Germany
4. Dubois DJ (1980) Fuzzy sets and systems: theory and applications, vol 144. Academic Press, Massachusetts
5. Dubois DJ (1988) Possibility theory: an approach to computerized processing of uncertainty. Plenum, NY
6. Eshtehardian E, Afshar A, Abbasnia R (2009) Fuzzy-based moga approach to stochastic time-cost trade-off problem. Autom Constr 18(5):692–701
7. Gen M, Cheng R, Lin L (2008) Network models and optimization: multiobjective genetic algorithm approach. Springer Science and Business Media, Heidelberg
8. Harvey RT, Patterson JH (1979) An implicit enumeration algorithm for the time/cost tradeoff problem in project network analysis. Found Control Eng 4:107–117
9. Kaufmann A (1975) Introduction to the theory of fuzzy subsets. Academic Press, Massachusetts
10. Ke H, Ma J (2014) Modeling project time-cost trade-off in fuzzy random environment. Appl Soft Comput 19:80–85
11. Leu SS, Chen AT, Yang CH (2001) A GA-based fuzzy optimal model for construction time-cost trade-off. Int J Proj Manag 19(1):47–58
12. Long LD, Ohsato A (2008) Fuzzy critical chain method for project scheduling under resource constraints and uncertainty. Int J Proj Manag 26(6):688–698
13. Monghasemi S, Nikoo MR et al (2015) A novel multi criteria decision making model for optimizing time-cost-quality trade-off problems in construction projects. Expert Syst Appl 42(6):3089–3104
14. Nahmias S (1978) Fuzzy variables. Fuzzy Sets Syst 1(2):97–110
15. Wang P, Wang G, Hu Z (1997) Speeding up the search process of genetic algorithm by fuzzy logic. In: Proceedings of the fifth European congress on intelligent techniques and soft computing, pp 665–671
16. Weglarz J (2012) Project scheduling: recent models, algorithms and applications, vol 14. Springer Science and Business Media, Heidelberg
17. Xu J, Zhang Z (2012) A fuzzy random resource-constrained scheduling model with multiple projects and its application to a working procedure in a large-scale water conservancy and hydropower construction project. J Sched 15(2):253–272
18. Xu J, Zhou X (2011) Fuzzy-like multiple objective decision making, vol 263. Springer, Heidelberg
19. Xu J, Zheng H et al (2012) Discrete time-cost-environment trade-off problem for large-scale construction systems with multiple modes under fuzzy uncertainty and its application to Jinping-II Hydroelectric Project. Int J Proj Manag 30(8):950–966
20. Zadeh L (1965) Fuzzy sets. Inf Control 8(1):338–353

Chapter 112
Impulsive Buying: A Qualitative Investigation of the Phenomenon

Umair Akram, Peng Hui, Muhammad Kaleem Khan, Muhammad Hashim and Sehrish Khan Saduzai

Abstract The emphasis of this study is to explain the concept of impulsive buying behavior. Numerous definitions and clarifications of the singularities are examined. Impulsive buying had an important factor in the point of view of consumers as well as retailers. Model shown in this study is to classify the conventional IBB and online. Impulse buying behavior. Most of studies have focused only on conventional IBB, thus online IBB remained ignored. Many studies have only focused on impulse buying not retail online impulse buying and its advantages and drawbacks. Present study is important in existing literature as it considers the in depth science behind the impulse buying behavior of customers when they shop traditionally as well as online and also highlights the differentials in both. As online buying behavior is at the verge of becoming a substitute of traditional buying, so it needs to more emphasis of researchers so that fruitful policies can be suggested. Conferring to the results of this study we should know the differences in advantages and disadvantages of conventional impulse purchase and online impulse purchase. This study expands the concepts of IBB in the context of online and its benefits.

Keywords Impulse buying behavior · Online impulse buying behavior · Retailer and consumer

112.1 Introduction

Shoppers often face enticement to purchase items that are not on their shopping lists ubiquitously they go. This enticement to make redundant purchases eventually leads to consumers making impulse purchases. All customers are somehow engaged in

U. Akram · P. Hui · M. Khan · S. Saduzai
School of Economics and Management, Beijing University of Posts and Telecommunications, 100876 Beijing, People's Republic of China

M. Hashim (✉)
Faculty of Management Sciences, National Textile University, Faisalabad 37610, Pakistan
e-mail: hashimscu@gmail.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_112

impulse purchases at some point in their lives. With our society enduring to become more materialistic, marketers have to develop new strategies to make the consumers convinced that their product or service is worth purchasing even if it was not being sought after at the time of purchase. Research specifies that nine out of ten shoppers purchase items on impulse (9 Out Of 10, 2012), and that only 40 % of consumers will say that purchases they sort on impulse are for discretionary items [12].

Prominence of impulse buying has been well recognized by researchers and marketers all around the world [9]. Recognized importance of impulse buying in retail setting and firstly introduced the notion of impulse buying in marketing literature. This was followed by numerous researchers from a variety of fields, such as consumer behavior, psychology, economics and marketing etc. Canadian grocery chain was pragmatic that its profitability would surge by more than 40 percent if each customer purchased an additional item on impulse [14]. Significance of customer's impulsive buying behavior is well renowned and it has endured vital part of analysis over many years and since being comprehensively wilful all over the world. This most important phenomenon has been a key research area of scholars during last 60's years. Initial studies on impulse buying include DuPont consumer habit studies in 1940–1960s, and studies by Patterson in 1960 on point of sale advertising. Impulse buying is simply defined as abrupt buying or a product or service from a store with no prior intensions attached. Impulse buying has also been defined as the discrepancy between product that buyer had a plan to buy afore ingoing store and product that was truly purchased [23]. Impulse buying occurs when a consumer is influenced and persist urge to buy instantly. Today nearly 70 per cent of all procuring verdicts are made at the point of purchase, which makes impulse purchases version for an extensive volume of goods sold across a wide range of artefact categories. The applied perspective on impulse purchases lures on [16, 50] who highlight variances between reminder impulse buying (in-store recollection of needed items) and planned impulse buying (shopping for price discounts). It is suggested that the reminder impulse buying is predominantly pertinent on purchases of everyday groceries since many consumers spree for groceries under time pressure on their way home from work, and hence, experience need to reduce amount of time spent on decision-making while shopping. However, although time for shopping groceries is partial, consumers tend to purchase more products than those on their shopping lists. Planned shoppers are not involved in impulse buying due to their full concentration on selective products which they want to buy. Due to advancement in packaging technologies in contemporary society, repaid and un-planned buying decisions among consumers have been experienced which might end up with satisfaction or dissatisfaction of products. Impulse buying is unplanned buying decisions which are made without gagging the product. There are different factors that influence a buyer for impulse buying; some of them are internal factors. Such factors include store appearance, in store display, product assortment, interior, store image, store size, store location, and different types of discounts [3]. On the other hand there are some external factors too which are ceremonial and are the marketing cyphers that are used by the marketer in shot to entice consumers into impulse buying behavior [24]. These factors include promotion and the sales strategy and marketing efforts. Consumers usually make impulse buying due to special sale prices, free shipping and seasonal promotion. Consumers who involve in impulse buying are social, status conscious and more images concerned. Impulse buyers tend to experience more anxiety and difficulty in controlling their sentiments and therefore are likely to experience less happiness; so, in order to experience happiness they are more inclined towards impulse buying. People who involve in impulse buying are less likely to consider consequences of their spending. People who like to sort fun are more likely to buy on impulse [55]. Recent research concludes that people who buy product impulsively are agreeable with their products and show favorable behavior towards their shopping articles.

Advancement in technology has given rise to use of websites by the marketers for exploiting the impulse buying. This is only possible when retailers put their efforts in making their websites more attractive and fancifully showing products on websites. With e-commerce on upsurge, consumers are even more apt to make an impulse purchase because there are now multiple media that a product can be purchased from. For example, consumers can shop at traditional brick-and-mortar stockpiles or on websites in the coziness of their home. Now, e-commerce has already become a part of online shopping, because of how calm and stress-free it is to go shopping online. Impulse e-commerce is a manipulation technique, meaning that it relies on customer's mind to show off his potential irrational buyer behavior and apply it in real-life. Logical sequence of consumers' actions is substituted with an irrational moment of self-gratification. Impulse items appeal to emotional side of consumers. Online impulse buying is a subject of tremendous interest. Customers are operating Internet to buy more items and services. Essentially, a few sites depend exclusively on drive buys. Sites that depend exceptionally on motivation buys, alluded to as revelation based shopping locales, work in light of drive purchasers. A significant part of the examination about online motivation purchasing occurred before the development of cell phones and social networking. Today's associated buyers are in a position to purchase hastily anyplace and at whatever time. Shoppers are likewise more prone to settle on motivation purchasing choices at online sites they trust. Such locales have great substance, are anything but difficult to utilize, have an engrossing client experience, are intuitive and are customized to guests' necessities and relaxations. When they find such a site, they will continue returning to make both judicious and motivation purchasing choices. One who tends to make such buys is alluded to as a drive buyer or impulse buyer. Research discoveries recommend that feelings and emotions assume a conclusive part in seeing so as to buy impulsively, activated item or upon introduction to a very much created limited time message. In online impulse buying social media played very important role because catchy and elegant pictures on websites force people to buy impulsively online. A social media source for impulse e-commerce purchases is probable to be most effectual way of endorsing impulse purchasing when it is done accurate. It is thought that tranquil procedure of check-out, which doesn't many intricate steps will influence stimuli, hence will promote impulse buying.

Marketers have relied on impulse purchasing practices for eras now, thus endorsing their products and engendering last-minute sales. But since e-commerce has taken over extensively (statistics report up to 9 % of income spent online), marketers' and

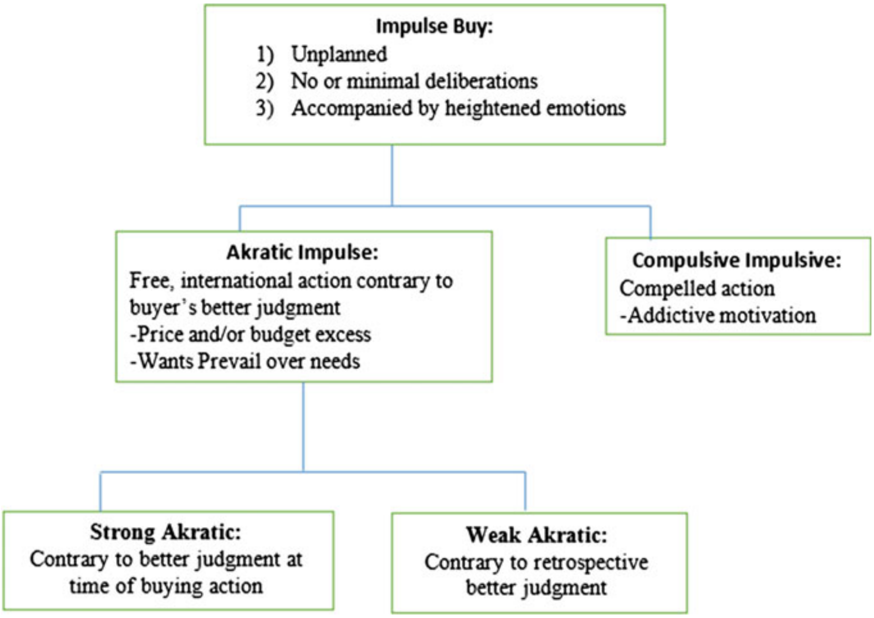


Fig. 112.1 Types of impulse buying behavior

sellers' confronted needs to transition from offline to online procedures of manipulation in regard with consumer behavior during online shopping, and sensations of impulse e-commerce will be discussed in detail in this paper. Technology does not create impulse buyers, but it affords impulse buyers additional resources to shop and capacity to complete the transaction in short time period, make those acquisitions truly a reaction to an impulse. When found out online, erratic studies covering the impulse buying in online environments can be seen (Fig. 112.1).

112.1.1 Research Objectives

- To describe the concept of impulse buying behavior.
- To define the importance of online impulse buying from the perceptive of Retailer.
- To describe the importance of online impulse buying from the perceptive of Consumer.
- To identify the variables related to online impulse buying.

112.1.2 Research Questions

- What is the importance of online impulse buying from the perceptive of Retailer?
- What is the importance of online impulse buying from the perceptive of Consumer?
- What are the important variables related to online impulse buying?

112.1.3 Significance

Work done on online impulse buying is still far from enough. This study will be valuable to both professionals and scholastics; it could help online advertisers and webpage fashioners to distinguish issues requiring unique consideration when outlining and assembling their online firm or evaluating their current online endeavor. For scholastic analysts this study could be a premise for the design of new speculations and inspection inquiries prompting better mapping of the online shoppers' conduct. The study could likewise serve as a basis for further research concentrated on better conception of nature and weight of Web experience components, either in isolation or in connection with one another and in diverse virtual market settings.

112.2 Literature Review

112.2.1 Impulse Buying

Notwithstanding the portrayals of rash and non-unwise buyers, it was in like manner found that the level of absence of alert in reference to getting contrasted structure time to time for both the careless buyers and non-hasty buyers [54]. It was found that each one of the general populations has gathered in tactless spending frameworks: (1) Desire to buy, and (2) Ability to control slant of obtaining. Exactly when the past overpowers later then it results in hasty spending. Free people get induced by (1) their own specific slant (2) Needs, and (3) Rights. More over these people offer need to their own particular targets and complement on typical relationship with others [23]. It is normal that individuals organized, as free thinker will have a more grounded relationship with hurried buyer when appeared differently in relation to individuals who are named group [23]. Purchasers have demonstrated that by as of late looking at the things in stores or records can sustain longings for the purchase of stock. Physically closeness moreover strengthen unmistakable inputs, for instance, (1) touching items in store (2) tasting free example of foods, which in like manner impact wish [54]. According to [45], this article depicts the parts which effect drive acquiring, for instance, external jars (buying repeat, store showcases, progressions and advancing, air in the store and retailers), inside perceptions (lifestyle, character, feeling, money, and time weight), buying behaviour (esteem, the season of getting, portion) and demographic variables (age, sex, pay, occupation, marital status, guideline, family unit pay, and societal position). It is key for sponsors to think about these four parts with the objective that they can make a complete and functional showcasing course of action. Various obtaining circumstances lead to unmistakable drive buying practices. The effect of three components (showcasing helps, quality impulsivity and situational segments) in beginning inspiration obtaining may change in the middle of individuals, and moreover between unmistakable occasions for the same individual [13].

There is an affinity for buyers to buy indiscreetly when they are voracious and acknowledge shopping. The extra time is open, the more huge the likelihood that a customer will make a purchase. A customer with a strong slant toward inspiration obtaining will most likely make a purchase than one with a feeble penchant [45]. Then again, growing one's balance avoids drive obtaining. Babin et al. [2] found that in stores purchaser's purchasing points and spending can, as it were, be influenced by emotions. These emotions may be specific to particular things for example, the components of the things, customer's self-interest, purchaser's gage of evaluating things and the hugeness they accommodate their getting at a store. Babin et al. [2] argued that youngsters, assortment in imprudence by age may be greater than for adults, resulting to the energetic change stage is noted for impulsivity. However, examination of hurried obtaining by youngsters of particular ages would be an imperative duty to the written work. Different store atmospherics experts Sharma et al. [46], Skandrani et al. [48], Russo et al. [42] have hoped to choose the effects of distinctive store ecological qualities on customers. Those inventors after considering a lot of factors found that the natural attributes of a retail store effectively influence customer's mind-set and behavior. Sharma et al. [46] found that a beguiling shopping environment completely impacts shopping time and trade spent out in a store, and furthermore the general eager state joined with shopping. As showed by [43], character is novel and component relationship of characteristics of a particular individual's physical and mental approach which effects behavior and responses to the social and physical environment.

Conspicuously, the traits based procedure has been in ascendency due to the consideration on the quantitative estimation of personality [49] and the most enticing quality philosophy happens to be the five sweeping trademark parts called the Big Five [25] approach. With various studies confirming that dependably the tremendous five segments created in unmistakable masses of individuals [30] in this way it would not bean twisting to express that the gigantic five model has finished most conspicuous level of assertion among all trademark investigative orders [10, 25] and the advancement of five-component model has engaged experts to focuses on a middle plan of behavioral properties extraversion, neuroticism, propriety, con-scientiousness and openness to experience.

A couple of investigators [10] trust that all estimations of character should be orchestrated through gigantic five and even exhibited that the colossal five model estimations have inherited subjects that apparently are inherent [5]. Needless to say, given the wide affirmation, the five creates of personality as indicated by the enormous five model have been investigated in association with the possible relationship with rash obtaining behavior (Fig. 112.2).

112.2.2 Online Buying Behavior

As a result of advancement in information technologies many people are using online shopping. A person's online shopping intensions can be measured by three variables

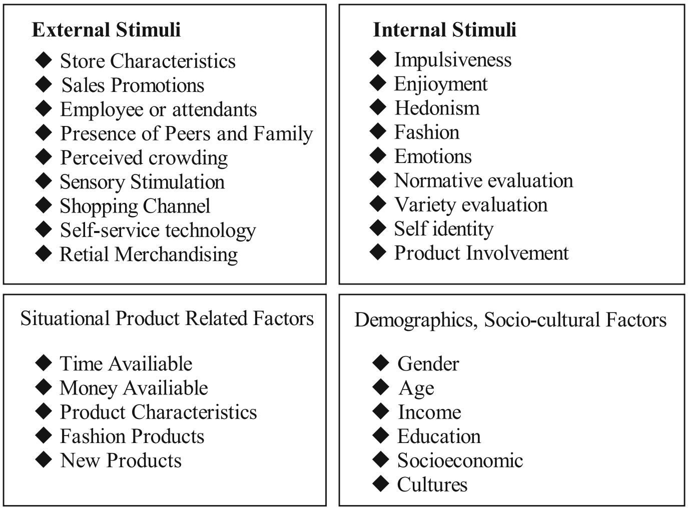


Fig. 112.2 Different factors influencing impulse buying behavior

(1) buy during that period (2) place stuffs in the online shopping cart (3) chance of buying while visiting online store [27]. Consumers mostly prefer to buy products online when they perceive they have enough information about product through online resource, they are provided with reliable product, the website gives them guarantee, the cost of shipment is low, and they receive a quick feedback after placing an online order [51].

Chang and Tseng [7] believed that worthy brand image of online store would directly make an impact on consumers' intension to buy product online. A sound brand image of online store would affect customers' cognitive on products and services hastening buying intensions. In online shopping buyers buy the product only when they have trust in online store they are buying from. This trust helps to build a long term relation and commitment of customers to buy product from the same online store again and again.

Inspected the impacts of presentation mode, web indexes, and route structure of item things on the appropriation of Internet shopping [8]. Presumed that trust in an Internet store is a notable determinant of web shopping. Customers like to purchase items online on the grounds that it gives purchaser the data and decisions to look at the cost and the item, extends more comfort, and discovers any kind of items effectively [18]. At the point when buyers make intension to purchase item on the web, firstly they see item promotions; this kind of commercial may get client's consideration and initiates longing to purchase item. Before they choose to purchase item, they require extra data about item that will bail them out. On the off chance that they don't have enough data about item, they will look through online channels e.g. online lists, site, and distinctive sorts of internet searchers [29]. At the point when clients have enough data, they should think about those decisions of items or administrations. In the pursuit stage, they may search for the item audits or client remarks. They will discover which brand or organization offers them the best fit to their desire. Amid this stage, all around sorted out site structure and the alluring outline are imperative things to induce shoppers to be keen on purchasing item and administration [26]. At the point when shoppers need to purchase item, they will take a gander at the brand and the attributes of item. A few items can be obtained and transported effortlessly online, for example, software books. Then again, a few items are difficult to choose through online channel. Site elements, firm capacities, promoting correspondence jolts, and buyer aptitudes are likewise imperative, as far as the proposed structure [29]. Also, the online shoppers take a gander at the brand and the qualities of item or services. A few items can be acquired and transported effectively online, for example, programming books. Then again, a few items are difficult to choose through online channel. Site highlight is one of the essential things that can impact customers to purchase item on the web. For instance, online retailers can utilize high innovation to enhance their sites keeping in mind the end goal to impact buyer impression of the web environment [38]. Websites are the important thing that influence buyer to buy product online. For this online retailers can use high technology to improve their website and to make it more attractive for buyer [38]. If websites do not provide adequate information, are not too much responsive, and do not provide safe environment then it will create negative impact on consumer online buying behavior [39]. Buyer online shopping states to awareness of buyer about artefact and know-how of procedure to shop the product online. Clickstream is also an important characteristic in online buying. It denotes to the comportment that consumer find the information about articles by using different sites in the same time, then to a single site, then a single page and finally make intension to buy product online [29]. In online shopping, website quality and atmosphere have a positive impact on consumer online buying satisfaction and more influence on online buying intension. Security, privacy and quality services have a significant on consumer buying intension [19]. Consumer prefer to buy product online because products are available round the clock and online stores are open 24 h, 7 days a week; such conveniences influence the consumer to buy product online [20]. Cost and time efficiency are other important factors that influence consumer to shop things online because online shopping gives the opportunity to consumer to buy the product at low cost and at the same time allows to compare prices by visiting different types of websites. For example Ebay offers the customers with auction option, so they can make a good contract for their product. This type of website makes the shopping a real game of chance and provides fun and entertainment. Since online shopping can be anywhere and at any time, it makes life tranquil as the customer do not need to worry about from where and when to buy a product; they never face crowds like they usually do in traditional stores (Fig. 112.3).

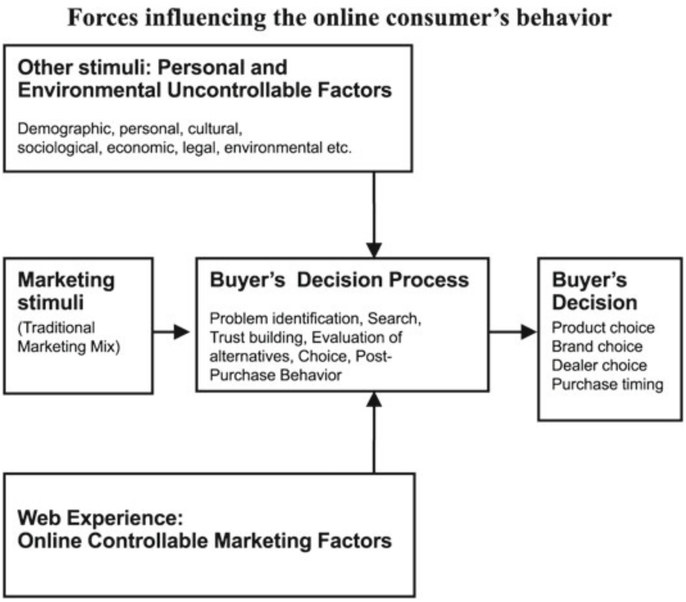


Fig. 112.3 Factors effecting the online consumer's behavior (Source the P. Kotler's framework (2003) [37])

112.2.3 Online Impulse Buying Behavior

As the result of improvement and innovation in technology more and more people are now enticed to online impulse buying. With increasing of online retail sale, companies are trying to capitalize on the convenience of online shopping by using different types of strategies that encourage the impulse buying. With the advancement in technology and increased experience of online marketing, websites have become very innovative and lure buyers into impulse buying. Some websites truly rely on impulse buying; websites like RueLaLa.com, ideeli.com and Haute Look.com, are different types of websites that gyrate around customers' impulse to buy.

It is very important for retailers because they are trying to find ways to motivate consumers to buy more and more. 40 % impulse buying occurs due to online process [52]. Influence of consumer's general tendency to buy impulsively on consumer intension to buy online as part of a modified TAM model is examined [57]. The other issues covered in the studies are factors influencing online impulse buying [22], relationship between online store dogmas and consumer online impulse buying behavior [52], relationship among product characteristics, web browsing and impulse buying for attire products in internet context [21], stimulus of people mood in online buying decisions [21], and websites cues influence on online impulsiveness. Individual differences influence on online impulse buying behavior of buyer, effects of electronic service quality dimensions on costumers satisfaction and buying impulse. Besides these studies [31] defined online impulse buying with the help of psychology discipline. He pointed out that in order to gain deeper insights into online impulse buying one should need to understand consumer inherent traits and his/her current state of mind. Personality traits are individual physiognomies that can be used to distinguish between two individuals. On the other hand mental states signify characteristics of individuals that tend to change depending on environmental surroundings [31] suggested a term known as ‘web atmospherics’ inclusive of certain web design features such as frames, graphics, text, search engine, pop up window design, one click, hypertext links, check out and purchase process, media dimensions (audio, colour, streaming video) and site layout dimensions (grouping of merchandise); these website elements may contribute to triggering online impulse buying. Liu et al. [31] exposed that visual appearance of website, easy use of website and product availability are imperative antecedents of online impulse buying. Mohammed and Alkubise [34] depicted that features of website (navigation, customized preview and visual appearance) are three important characteristics of serving consumers pleasurably and increasing their commitment to site hence increasing online impulse buying. It is important to realize personality traits when online impulse buying literature is going to conduct. Personality traits are also important in online impulse buying [31, 57]. Personality traits are used to portray the consumers’ online impulse buying behaviour as they have greater influence on online impulse buying [35]. For example if a person is extroverted (bold, talkative, stylish, social, energetic) then he/she will prefer to buy things impulsively because he/she has to take less time to think due to his/her bold and charming personality. When this type of personality views things online on such a website that bears attractive adds and graphics, he / she quickly buys things online [6]. Online impulse buying would not be influenced by product characteristic but the features of shopping environment (Websites) [32]. Moreover, the websites that provide special offers create positive sentiments in consumers hence urge to buy things impulsively. Product attractiveness by using different types of customized pictures, graphics, easy to use buying process, and in time delivery process can force buyers to buy thing impulsively [57]. Website’s communication style is important aspect that can also have an impact towards impulse buying. Website communication style reflects thoughtfulness of approach (Calm instead of aggressiveness), its social orientation (friendly relationship), and providing complete knowledge about products attract customers to buy quickly [11]. Online store gratification can be stimulated by music in background and visual fun effects. It can have significant effect on consumer emotions. If a marketer adds different type of visuals arts, picture comic strips, and cartoons then it may create positive affect on consumers [53].

Different types of website features will upsurge website hedonic value. For example a website’s pleasantness is an important determinant of websites users choose to browse [36]. In the same way, visual appeal, which relates to selection of words and other visual elements such as graphics, increases the overall appearance of website [15]. There are four important variables of websites that urge user to buy product online, (1) draught of website (2) easy navigation (3) colour configuration, and (4) professionalism. Chang and Tseng [7] defined online impulse buying such that consumer will (1) visit web store again and again (2) purchase the product in short run and in less time (3) always consider the web store in mind whenever he/ she wants to buy anything at any time, and (4) make long run relationship with online retail store. Rababah [40] defined that consumer will quickly buy the product online when website provides (1) enough information (2) quick response to the customers complaints (3) attraction (4) easy contact to the retailer (5) calm use of website, and (6) feedback to customer on online dealings.

Yao and Liao [56] observed that consumer will quickly involve in impulse buying when online store may produce favorable impression to customer through providing high quality online services. Such service includes significant magnitudes (1) link (2) attractiveness (3) security (4) credibility (5) reliability (6) tranquil use of website (7) easy language of website (8) punctuate transfer of product, and (9) definite return strategies. Abdulhadi [1] defined that product features can influence customer satisfaction and increase customer intension of maintaining long term relationship with online store; moreover increase the popularity.

An article in PC World defines member want to shop online, ticking clock, discounts and knowledge of an item that has the ability to grab the customer's attention are technique for impulse buying. For a consumer it is very delightful experience to buy the discounted product. These types of quick sale websites (RueLaLa.com, ideeli.com) have become very popular in order to encouraging buying impulsively. Most of customers are cognizant of what they are going to do, buy still rely on their feelings when they view a product online with a tag of discount or limited offer. Due to this, types of offers grab the customer's attentions and impel them to buy the things impulsively. When the customers are in store they might have time to think before buying a product but when they buy a product online they do not have enough time to think [44]. For a website to increase impulse buying it is essential that its visitors fell satisfied with quality of website, including both utilitarian dimensions (easy to use and security) and hedonic (design of website). A visitor prefers to use online buying instead of traditional stores because of design and easy buying process. Research shows that security, information clarity and privacy can influence emotional behaviour such as impulse buying (Bressolles, Durrieu and Giraud).

112.3 Facets of Impulse Buying—the Retailer's Perspective

Retail advancements are expected to build benefit of retail locations and different item classes. Retail advancements can be a coupon for instance a $5 off on a buy of $30 or more. This coupon may lure the buyers to attempt their store over their typical retailers which make "store substitution" [28]. This is noteworthy to the retailer on the grounds that they will expand their client base amid that advancement and conceivably procure more clients over the long haul.

A noteworthy issue that retailers are at present confronting with advancements and coupons is the way that a few customers have ended up "coupon hoarders" [33]. These purported hoarders have made couponing a fixation to the point where they won't purchase things unless they are on special and will purchase things in mass when they are at a bargain. For instance, a lady obtained her family "150 pockets" [17] of fish that kept going her family 18 months when it was 50 pennies off and combined with a retailer coupon, making the fish basically free. A report by Nielsen confirmed that coupon use by families was 13 % up from 2009 at 11 %. Also, of these 13 %, "70 % were recovered by lovers, which is characterized as individuals who purchased no less than 188 things utilizing coupons for each year" [33]. This conveys difficulties to the retailer and has created retailers, for example, Target and Walgreens to renovate their coupon approaches keeping in mind the end goal to pledge that they stay valuable off of the coupon aficionados.

112.4 Facets of Impulse Buying—the Consumer's Perspective

Impulse purchasing can be invaluable to shoppers in a couple of ways. A shopper may have neglected to compose a thing on their shopping rundown and be helped to memorize thing taking into account condition in the store while they are shopping. This kind of drive buy is not destructive to the customer in light of the fact that time is spared by not making another outing to the store after the shoppers find that they neglected to compile a thing on their rundown. This frequently happens in the diet business on grounds that there are plentiful fixings that go into a formula and the purchasers could neglect to compose a thing on their rundown. For instance, a lady making chocolate chip treats will go down the preparing walkway to get the flour, sugar, chocolate chips, and oil. The buyer may have overlooked the heating pop; however, since it was right beside the flour, she recalls that she needs that thing too. Another favorable position of drive buys is that they give worth to the purchaser. This quality is regularly taking into account feelings in that the buyers accomplish an assortment of emotions in the wake of purchasing a thing that they didn't require or did not plan to purchase. A few buyers consider shopping energizing and feel that it briefly numbs any negative feelings that they are encountering, making a drive by the ideal "snappy fix" to their day.

Drive buys don't generally furnish buyers with preference. These days, numerous individuals are attempting to make a decent living and are on tight spending plans. In the event that advertisers deliberately put items and uncover outer signals, customers will probably make a drive by and surpass their financial plan in the event that they buy on motivation again over again. While examining the impacts of retail and producer advancements, shoppers are uninterested in the middle of maker and retailer refunds [47]. This is because of the way that purchasers are driven by outer advancements and hardly pay consideration to where the advancements originate from. Purchasers react diversely to a value decrease versus a reward thing, yet they react the same way no matter a producer puts forth it or a retailer.

112.5 Marketing Implications

In view of this, it is imperative for retailers to perceive why buyers shop the way they do with a specific end goal to separate themselves from the makers. For instance, the way that the vast majority of customers buy things on drive is critical in light of the fact that this demonstrates the significance of brands having a vicinity in the stores whether through print advertisements, advancements, or having the brand at the right area in the store. Drive buys are so predominant among U.S. customers on the grounds that it is perceived as a chance to fulfill a "long-felt need or yearning" [4]. Buying on drive can make a buyer feel more appealing, "empower us to accomplish something we need to do, or it will compensate us for commendable conduct before" [4]. Buyers acquiring on motivation may be purchasing the thing for various reasons, however the most critical reason is the way that buyers are attempting to "feel" a sure way or accomplish some sort of enthusiastic reaction.

A standout amongst the most vital elements of a retailer's prosperity is the measure of "stroll in" movement the store pulls in. These customers merit consideration from the store agents in light of the fact that they are effectively judging the stock accessible in the store. These clients who stop in a store only to browse regularly purchase things on motivation. What's more, on the off chance that they don't purchase on motivation right then and there; they may rather see a thing they like and recall it for a future buy. Consider the predominance of this circumstance: a store assistant inquires as to whether they need assistance saying so as to discover something and the client reacts "ass, I'm simply glancing around". This announcement is extremely common in our general public in light of the fact that we have taken up "unconstrained shopping" [37] which is the delight of purchasing something unneeded or impromptu. This unconstrained shopping wonder prompts an increment in motivation buys. Retailers that influence this will make their stores luring and attract clients so that they simply "glance around" and trust that they leave with something that they didn't anticipate purchasing. An extraordinary case of a retailer utilizing a strategy to impel this is Bass Pro Shops Outdoor World. The retail location has angling posts that you can experiment with, lakes with fish swimming around, and old wooden water crafts that have chronicled hugeness. This air in the store should reproduce the open air encounters that the purchaser will be confronted with (angling, chasing, outdoors, and so forth) and subsequently expand the shopper's solace level and drive buys.

After the retailer baits the client into the store, the following advertising strategy that the retailer must know about is the way that the additional time individuals spend in a store the more they will purchase. Along these lines the retailer must guarantee an agreeable and simple design of the store for the client's accommodation. The less demanding it is for the purchaser to explore the store, the more they will shop at that store. Be that as it may, on the other side, retailers need to have the purchasers wait in their stores as far as might be feasible in light of the fact that "the measure of cash we spend in general stores is attached to the measure of time we spend in them" [4]. So the retailer must have a parity of simple access and vital situation of items to guarantee that the clients spread whatever number walkways as would be prudent. Canine nourishment, for instance, is amidst the path with the greater part of the open air things and paper items. This is on account of the retailer needs to have the client go by the greater part of the paper items that they may have overlooked that they need and hence buy it despite the fact that they had no expectation of doing as such.

112.6 Limitations and Future Directions

Whereas this study produced some valuable contributions, but still it also has some limitations. This study just focus on the qualitative approach to describe the IBB and online IBB and also its advantages and disadvantages. Future research can examine the relationship between personal factor, situational factor, website quality and sales promotions on online IBB. Additionally, future research can be identified the answers of these questions (1) How website quality effect on impulsive buying? (2) What is the relationship between sales promotions and online IBB? (3) How do consumer's personal factors influence on IBB? Why in-store factors positively and negatively influence on IBB? Further inclination flowing online purchasing, research examinations could be undertaken to measure the impact of these factors in online context and different geographical areas where most of the population believes on buy goods online like China and USA.

Acknowledgments The authors want to extend their gratitude towards the Editor and the anonymous Reviewers for their indispensable and valuable suggestions and comments that improved the quality of the paper significantly. Furthermore they thank Prof. Peng Hui for valuable suggestions.

Appendix. Impulsive Buying Scale

Rook and Fisher [41] identified the following buying impulsiveness scale.

- I often buy things spontaneously.
- "Just do it" describes the way I do things.
- I often buy things without thinking.
- "I see it. I buy it" describe me.
- Sometimes I feel like buying things on the spur of the moment.
- I buy things according to how I feel at the moment.
- I carefully plan most of my purchases.
- Sometimes I am a bit reckless about what I buy.

References

1. Abdulhadi H (2013) An empirical study of online shopping customer satisfaction in malaysia-evaluating ebay Malaysia. J Comput Organ Dyn 1(2):36–62
2. Babin BJ, Darden WR, Griffin M (1994) Work and/or fun: measuring hedonic and utilitarian shopping value. J Consum Res a:644–656
3. Bei LT, Chen EY, Widdows R (2004) Consumers' online information search behavior and the phenomenon of search versus experience products. J Family Econ Issues 25(4):449–467
4. Berger AA (2004) Shop'til you drop: consumer behavior and American culture. Rowman & Littlefield Publishers, Maryland
5. Birtwistle G, Moore CM et al (2005) Bricks, clicks, and pix: apparel buyers' use of stores, internet, and catalogs compared. Int J Retail Distrib Manag 33(4):271–283
6. Bressolles G, Durrieu F, Giraud M (2007) The impact of electronic service quality's dimensions on customer satisfaction and buying impulse. J Custom Behav 6(1):37–56
7. Chang EC, Tseng YF (2013) Research note: E-store image, perceived value and perceived risk. J Bus Res 66(7):864–870
8. Chiu CM, Hsu MH et al (2012) Re-examining the influence of trust on online repeat purchase intention: the moderating role of habit and its antecedents. Decis Support Syst 53(4):835–845
9. Clover VT (1950) Relative importance of impulse-buying in retail stores. J Mark 15(1):66–70
10. Comegys C, Hannula M, Váisánen J (2009) Effects of consumer trust and risk on online purchase decision-making: a comparison of finnish and united states students. Int J Manag 26(2):295
11. Constantinides E (2004) Influencing the online consumer's behavior: the web experience. Internet Res 14(2):111–126
12. Danziger A, Wood (2004) Interactive home shopping: consumer, retailer, and manufacture incentives to participate in electronic marketplaces. J Bus Res, pp 38–53
13. Dholakia UM (2000) Temptation and resistance: an integrated model of consumption impulse formation and enactment. Psychol Mark 17(11):955–982
14. Eroglu SA, Machleit KA, Davis LM (2001) Atmospheric qualities of online retailing: a conceptual model and implications. J Bus Res 54(2):177–184
15. Estalami H, Maxwell S et al (2007) An integrated model of price, satisfaction and loyalty: an empirical analysis in the service sector. J Prod Brand Manag 16(7):459–468
16. Forsythe S, Liu C et al (2006) Development of a scale to measure the perceived benefits and risks of online shopping. J Interact Mark 20(2):55–75
17. Fortini A (2012) Honey, I got a year's worth of tuna fish. The New York Times Magazine
18. Garry T, Melewar T et al (2010) Transfer of brand knowledge in business-to-business markets: a qualitative study. J Bus Ind Mark 25(5):395–403
19. Ha S, Stoel L (2012) Online apparel retailing: roles of e-shopping quality and experiential e-shopping motives. J Serv Manag 23(2):197–215
20. Hausman A (2000) A multi-method investigation of consumer motivations in impulse buying behavior. J Consum Mark 17(5):403–426
21. Huang YF, Kuo FY (2012) How impulsivity affects consumer decision-making in e-commerce. Electron Commer Res Appl 11(6):582–590
22. Jeffrey SA, Hodge R (2007) Factors influencing impulse buying during an online purchase. Electron Commer Res 7(3–4):367–379
23. Kacen JJ, Lee JA (2002) The influence of culture on consumer impulsive buying behavior. J Consum Psychol 12(2):163–176
24. Karbasivar A, Yarahmadi H (2011) Evaluating effective factors on consumer impulse buying behavior. Asian J Bus Manag Stud 2(4):174–181
25. Keeney RL (1999) The value of internet commerce to the customer. Manag Sci 45(4):533–542
26. Koo DM, Ju SH (2010) The interactional effects of atmospherics and perceptual curiosity on emotions and online shopping intention. Comput Hum Behav 26(3):377–388
27. Kukar-Kinney C (2010) The effect of shopping emotions and perceived risk on impulsive buying: the moderating role of buying impulsiveness trait. Seoul J Bus 14(2):67–92

28. Kumar V, Leone RP (1988) Measuring the effect of retail store promotions on brand and store substitution. J Mark Res pp 178–185
29. Laudon K, Guercio C (2009) E-commerce., Negocios, Tecnologa, Sociedad, Editorial Pearson EducaciónCuarta Edición, México, Chicago
30. Liao H, Chuang A (2004) A multilevel investigation of factors influencing employee service performance and customer outcomes. Acad Manag J 47(1):41–58
31. Liu Y, Li H, Hu F (2013) Website attributes in urging online impulse purchase: an empirical investigation on consumer perceptions. Decis Support Syst 55(3):829–837
32. Madhavaram SR, Laverie DA (2004) Exploring impulse purchasing on the internet. Adv Consum Res 31(1):59–66
33. Mayer M (2011) When clipping coupons becomes extreme. Snack Food & Wholesale Bakery, 100(8)
34. Mohammed AB, Alkubise M (2012) How do online advertisements affects consumer purchasing intention: empirical evidence from a developing country. Eur J Bus Manag 4(7):208–218
35. Parboteeah DV, Valacich JS, Wells JD (2009) The influence of website characteristics on a consumer's urge to buy impulsively. Inf Syst Res 20(1):60–78
36. Park EJ, Kim EY et al (2012) Apparel product attributes, web browsing, and e-impulse buying on shopping websites. J Bus Res 65(11):1583–1589
37. Pooler J (2003) Why we shop: Emotional rewards and retail strategies. Greenwood Publishing Group, Santa Barbara
38. Prasad CJ, Aryasri A (2009a) Determinants of shopper behaviour in e-tailing: an empirical analysis. Paradigm 13(1):73–83
39. Thamizhvanan A, Xavier MJ Determinants of customers' online purchase intention: an empirical study in India. J Indian Bus Res 5(1):17–32
40. Rababah O (2013) Online shopping: perceptions and expectations of the students at the university of Jordan. J Am Sci 9(3):66–71
41. Rook DW, Fisher RJ (1995) Normative influences on impulsive buying behavior. J Consum Res pp 305–313
42. Russo Spena T, Caridà A et al (2012) Store experience and co-creation: the case of temporary shop. Int J Retail Distrib Manag 40(1):21–40
43. Schiffman L, Kanuk L (2010) Consumer behavior. Prentice Hall, New Delhi
44. Schlosser AE, White TB, Lloyd SM (2006) Converting web site visitors into buyers: how web site investment increases consumer trusting beliefs and online purchase intentions. J Mark 70(2):133–148
45. Shang RA, Chen YC, Shen L (2005) Extrinsic versus intrinsic motivations for consumers to shop on-line. Inf Manag 42(3):401–413
46. Sharma A, Stafford TF (2000) The effect of retail atmospherics on customers' perceptions of salespeople and customer persuasion: An empirical investigation. J Bus Res 49(2):183–191
47. Sigué SP (2008) Consumer and retailer promotions: who is better off? J Retail 84(4):449–460
48. Skandrani H, Ben Dahmane Mouelhi N, Malek F (2011) Effect of store atmospherics on employees' reactions. Int J Retail Distrib Manag 39(1):51–67
49. Soloman MR (2010) Consumer behavior: Buying, having and being. Pearson Education
50. Stern H (1962) The significance of impulse buying today. J Mark pp 59–62
51. Swaid SI, Wigand RT (2009) Measuring the quality of e-service: scale development and initial validation. J Electron Commer Res 10(1):13
52. Verhagen T, van Dolen W (2011) The influence of online store beliefs on consumer online impulse buying: a model and empirical application. Inf Manag 48(8):320–327
53. Verhagen T, Van Dolen W (2009) Online purchase intentions: a multi-channel store image perspective. Inf Manag 46(2):77–82
54. Vohs KD, Faber RJ (2007) Spent resources: self-regulatory resource availability affects impulse buying. J Consum Res 33(4):537–547
55. Yao C, Liao S (2011) Measuring the antecedent effects of service cognition and internet shopping anxiety on consumer satisfaction with e-tailing service. Manag Mark 6(1):59

56. Yao C, Liao S (2011) Measuring the antecedent effects of service cognition and internet shopping anxiety on consumer satisfaction with e-tailing service. Manag Mark 6(1):59
57. Zhang X, Prybutok VR, Strutton D (2007) Modeling influences on impulse purchasing behaviors during online marketing transactions. J Mark Theory Pract 15(1):79–89

Chapter 113
Rebuilding Self-Control After Ego Depletion: The Role of Positive Emotions

Shiyang Gong and Qian Li

Abstract Ego depletion appears to exhaust individual's psychological resources, resulting in reduced self-control on subsequent tasks. Extrapolating from the relevant studies on positive emotions, we hypothesize that positive emotions would contribute to the replenishment of individual's psychological resources and rebuild self-control after ego depletion. We test this hypothesis in a lab experiment. After an ego depletion task, individuals were induced positive, neutral or negative emotions respectively by different movie clips, and then undertook a self-control task. The results show that, compared to neutral emotions, positive emotions could effectively reduce the impact of ego depletion. Individuals primed by positive emotions show higher level of self-control. On the contrary, negative emotions restrain the replenishment of individual's psychological resource. Individuals primed by negative emotions show lower level of self-control.

Keywords Emotions · Self-control · Ego depletion · Psychological resources

113.1 Introduction

Self-control are among the most prevalent and important topics in marketing and management studies. Research has shown that self-control decisions have significant implications for employees' and consumers' well-being. They found that people in low self-control could engage in impulse buying [23], make decisions based on affective response [7] and indulge in hedonic consumptions [19]. On the contrary, people in high self-control would persist in their work for long-term benefits [21],

S. Gong
Business School, University of International Business and Economics,
Beijing 100029, People's Republic of China

Q. Li (✉)
International Business School, Beijing Foreign Studies University,
Beijing 100029, People's Republic of China
e-mail: liq@bfsu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_113

engage in a positive activity such as exercise [22], as well as refrain from a negative behavior [20].

Many important psychological functions and individual behaviors need the participation of willpower, such as decision making, active response or inhibiting an action. Although studies have shown that some of the individual behaviors are spontaneous and unconscious [2–4], people always have deep consideration and proactively exert willpower to control themselves when taking into account the long-term interests (i.e. health, career development, etc.). Baumeister et al. [6] believed that the capacity of individual's willpower is limited. When people are exerting willpower to participate in psychological activities and behavioral decisions, their psychological resources would be depleted. Like natural resources running out after over exploitation, individual's inner resources will also be exhausted after overuse of willpower. In that case, individual's self-control will be reduced significantly, resulting in the behaviors inconformity to the long-term interests. Baumeister et al. [6] defined this phenomenon as ego depletion. These situations frequently arise in real life. For example, after an extremely boring class, most people feel mentally exhausted. Under the circumstance, they would probably put aside the ideas of keeping healthy and eat a lot of junk food (such as potato chips or fried chicken) instead.

How could people recover from ego depletion and restart self-control? Obviously, individual's psychological resources will not run out forever. Relaxation, rest and sleep are common ways to replenish psychological resources. The question is, these methods often require a long time. In many cases, however, people may not have much time to make psychological adjustment. Therefore, might there be some other ways to replenish psychological resources in a short time to rebuild self-control?

Recent findings showed that positive emotions (e.g. happiness, joy, contentment, love, etc.) had a significant impact on the reconstruction of psychological resources. Based on the literature, our research is to explore whether the stimuli of positive emotions can rebuild self-control after ego depletion. We propose that, positive emotions could help individuals to replenish psychological resources in a short time and to show higher level of self-control in subsequent activities. On the contrary, negative emotions may inhibit the replenishment of psychological resources, leading to lower level of self-control subsequently. Please modify your paper in using of English more professionally.

This study makes several contributions. First, it will empirically demonstrate a causal relationship between positive emotions and self-control. This will add to the growing literature on the positive emotions and the influence of positive emotions on consumer cognition and behavior. Second, we also compared the effect of different emotions After an ego depletion task, individuals are also primed by negative emotions and neutral emotions respectively. We are going to compare the effect of different emotions on self-control behavior.

In addition to theoretical contributions, this research also has important managerial implications concerning management, especially in employee and consumer well-being. Employees and consumers are encountered ego depletion all the days.

How to rebuild self-control in a short while after ego depletion becomes a critical issue for them. If our hypothesis is supported, we could suggest companies provide with some positive emotions stimuli, like provide some short funny videos for employees who encounter ego depletion in their work. Also for the employees themselves, they could also try to prime positive emotions by themselves, like try to memorize some happy moments or see some happy pictures, and rebuild higher self-control in the following tasks. For the consumer, if they suffer ego depletion and experience lower self-control, they are more likely to make some unhealthy choices for short-term interest (like choose burger and chips for lunch instead of a healthy salad), or do some impulsive shopping. In those circumstance, we suggest employees to prime themselves with positive emotions, like think about some happy stories for a short while. By doing this, consumers would replenish their own psychological resources in a short time and enhance their self-control in the following purchase.

This article is organized as follows. Firstly, we briefly review the extant literature on emotions, ego depletion and self-control. After this, we introduce our method, including the descriptive information about the participants and the experiment procedure. Following this is the result of our laboratory results. We show the results of manipulation check and our hypotheses. Finally, we conclude our study with a of main findings, theoretical and managerial implications as well as a discussion of suggestions for future research.

113.2 Literature Review

Our study draws on three streams of literature. First, Thayer's bio-psychological model indicated that emotions were highly related to physiological arousal. Typically, the physiological arousal of emotions include two major dimensions: energy, which enables people to effectively fight fatigue; and tension, which keeps people out of the sedation state. The positive emotions mainly evoke the energy dimension. Drawing on past work in this area, fatigue is an important physical manifestation of ego depletion. Many researchers suggested that individuals would report fatigue after ego depletion [6, 20]. Therefore, positive emotions may arouse energy to fight fatigue, thus offsetting the impact of ego depletion.

Second, Isen and her colleagues summarized four major functions of positive emotions through a series of studies [1, 15–17]. To begin with, positive emotions would promote pro-social behaviors, making people become more helpful and generous. Second, positive emotions had a significant impact on people's cognitive abilities by reinforcing memory and judgment. Third, positive emotions could improve people's ability to solve problems, making them more creative and innovative. Fourth, positive emotions affect people's motivation. By endowing with global view and long-term planning, individuals would act in accordance with the established goals. Isen [15] suggested that positive emotions can not only promote the psychological resources, but also contribute to the building of social resources.

Finally, our paper is also related to the broaden-and-build theory of positive emotions [10–12]. It described the forms and functions of a subset of positive emotions, such as happiness, joy, interest, contentment, love, etc. It suggested that the two key propositions of positive emotions were broaden and build. Broaden means positive emotions can expand people's momentary thought-action repertoire: happiness and joy sparks the urge to play; interest motivates the urge to explore; contentment stimulates the urge to savour and integrate; and love inspires people to build up close relationships. On the contrary, negative emotions will narrow people's thought-action repertoire, for example, making them trapped in the status of attack or flee. Build means that, after broadening the momentary thought Caction repertoire, positive emotions can promote the creative ideas, actions and social bonds, which in turn builds personal resources, including physical, intellectual, social and psychological resources. More important, these reserved resources can be utilized later to improve the probability of successful coping and survival.

Self-control is a core concept in management, especially in consumer research. It referred to self's capacity to alter its own states and responses, which includes thoughts, changing emotions, regulating impulses and altering performances [5]. Researchers have found that higher self-control may lead to better interpersonal relationships, higher performance and more savings. Consumers with high self-control is more likely to purchase based on the long-term value and benefits other than the stimuli at the moment. People's failure in self-control is an important cause of impulsive purchasing.

Therefore, combining the above theorizing, we posit that, relative to neutral emotions, positive emotions can replenish individual's psychological resources, thus offsetting the previous ego depletion and rebuilding self-control subsequently. On the contrary, negative emotions may inhibit the resource replenishment and result in lower level of self-control in subsequent tasks. Formally, we hypothesize the following:

Hypothesis 1 (H1): People who are primed by positive emotions after ego depletion are more likely to show higher self-control in subsequent tasks.

Hypothesis 2 (H2): People who are primed by negative emotions after ego depletion are more likely to show lower self-control in subsequent tasks.

We present a laboratory study with three tasks to test our hypotheses. Task 1 is an ego depletion task, which aims to deplete the individuals' psychological resources. Right after that, individuals are randomly assigned to watch one of the movie clips in either positive, negative or neutral emotions respectively. Following this, they are given an insolvable puzzle to work out. Obviously, for an insoluble puzzle, all the participants would result in failure. We record the total time each participant has spent before giving up as the measurement of self-control. Finally, participants are asked to answer the questionnaire on their personal information and then thanked with gifts.

113.3 Method

113.3.1 Participants

A total of 101 undergraduate and graduate students (55 % males) in a Chinese university were invited to participate in the experiment in exchange for a gift of 1.25 USD. Most of the participants were between the ages of 20–24 (94 %, Mean = 22). There were 68 undergraduates (67 %), 27 graduate students (27 %), and 6 doctoral students (6 %). See Table 113.1.

113.3.2 Procedure

The study was run in a laboratory setting. It contained three tasks: an ego depletion task, aiming to deplete the participants' psychological resources; an emotional task, aiming to prime positive, neutral, or negative emotions; and a self-control task, aiming to measure participants' level of self-control subsequently.

At the beginning of the experiment, participants individually entered the behavioral lab with privacy partitions and computers. Experimenter indicated that they were going to complete 3 unrelated tasks: working on two English articles, watching a movie clip as a relaxing break, and answering a Math Line Puzzle. They are unaware of the experiment purpose.

First, participants were given a short English article (9 lines, font 12) and asked to cross out the letter "e". All the participants learned this approach quickly and finished the task in a few seconds. During this process, they gradually formed the habit of crossing out "e". After that, participants were given a second English article, a two-page long article in a very small font. They were asked to cross out the letter "e" again, but the difference is that, if "e" is adjacent to the vowels "a, e, i, o, u", it should be left. It means that, participants have to give up their former habit of crossing out "e", and keep on working in a worse condition (smaller font, more pages). During this process, participants' psychological resources would be largely depleted, resulting in ego depletion [6]. To the end, participants were asked to rate the degree of fatigue in a 7-point Likert Scale (1 = not tired at all, 7 = very tired).

Table 113.1 Participants' descriptive information

Total number	101 participants
Undergraduates	68
Graduate and doctoral students	33
Gender ratio	55 % males
Mean of age	22

Right after the first task, participants were guided to watch a movie clip. Computers were set up in the front of each participant and they were randomly assigned to watch one of the four movie clips: in positive, neutral or negative emotions. Movie 1 (3 min 29 s) was extracted from the comedy “Mr. Bean”, describing a humorous story taking place when Mr. Bean was seeing the dentist. It was used for inducing the positive emotions of entertainment, happiness and joy. Movie 2 (3 min 12 s) was a short documentary recording the process of glassware production. It was the control condition of neutral emotions. Movie 3 (3 min 46 s) was extracted from the Japanese movie “Crying Out Love, in the Center of the World”. It was a touching dialogue between lovers before the girl passed away, which triggered the negative emotions of sadness. Movie 4 (3 min 24 s) was from the Hollywood movie “Vertical Limit”, describing the dangers two climbers encountered on their way of climbing. It manipulated the participants’ negative emotions of fear and anxiety. Each participant watched the movie independently and did not know they were watching different movies before the end of the experiment. Accordingly, we have four experimental conditions: movie 1 condition of positive emotions ($N = 27$); movie 2 condition of neutral emotions ($N = 25$); movie 3 condition ($N = 24$) and movie 4 condition ($N = 25$) of negative emotions. To the end, participants were asked to rate the extent to which they feel the seven emotions while watching the movie clips: amusement, sadness, happiness, fear, anxiety, joy, and anger (Emotion Report Form, adapted from [8]. The scale is 9-point Likert ranging from 0 = not at all to 8 = very strong.

Following the second task, participants were instructed to solve an insoluble Math Line Puzzle [9, 13]. They were asked to connect all the round dots with one line according to three rules: square was not permitted to be connected; diagonal line was not permitted, only vertical or horizontal line could be used; the line was not permitted to trace over itself or beyond the boundaries. Participants could try as many times as they want. The following final instructions were given before the questionnaire was presented to the participants.

Try to get the solution if you can. It is quite OK for you to take many trials and for any length of time as you wished. The evaluation is based on whether you could solve the puzzle, other than on the number of trails or the time you spent. The following questionnaire gives you the opportunity to try many times, if not enough, you can ask for new questionnaires from the experimenter. If you should feel that you’re not getting anywhere with the puzzle, please let us know at once.

Obviously, for an insoluble puzzle, all the participants resulted in failure. During this procedure, we recorded the total time each participant had spent before giving up, which is the measurement of self-control. Finally, participants were asked to answer the questionnaire on their personal information and then thanked with gifts.

113.4 Results

113.4.1 Manipulation Check

First, we verified that our ego depletion manipulation was successful. By the analysis of one-sample t-test, we found that participants reported their degree of fatigue significantly higher than the scale midpoint of 4 ($M_{\text{fatigue}} = 4.86$, $t(100) = 6.72$, $p < 0.001$). Additionally, after filling the questionnaires, many participants complained "always distracted", "eyes are dizzying", "anxious to have more "e" to cross out", etc.

Next, we verified the manipulation of emotions by analyzing the Emotion Report Form (ERF), which was given to the participants after watching the movie clips. Table 113.2 shows the results. Each movie clip successfully aroused the emotions we expected: Movie 1 induced higher levels of amusement ($M_{\text{amusement}} = 6.00$, $F(3, 97) = 86.50$, $p < 0.001$), happiness ($M_{\text{happiness}} = 4.11$, $F(3, 97) = 45.35$, $p < 0.001$) and joy ($M_{\text{joy}} = 4.55$, $F(3, 97) = 50.06$, $p < 0.001$); Movie 2 did not induce any positive or negative emotions; Movie 3 induced higher level of sadness ($M_{\text{sadness}} = 5.88$, $F(3, 97) = 131.43$, $p < 0.001$); and Movie 4 induced higher level of fear ($M_{\text{fear}} = 4.00$, $F(3, 97) = 21.71$, $p < 0.001$) and anxiety ($M_{\text{anxiety}} = 3.60$, $F(3, 97) = 13.73$, $p < 0.001$). Anger was not induced in any movie clip. Participants' emotional responses have no significant differences in gender, age or education.

113.4.2 Self-Control

We measured participants' self-control using the total time they spent in solving the Math Line Puzzle [9, 13]. The longer time subjects spent indicates the higher level of self-control they have.

Table 113.2 Results of emotion report form

Emotions	Movie 1 Mean (SD)	Movie 2 Mean (SD)	Movie 3 Mean (SD)	Movie 4 Mean (SD)
Amusement	$6.00 (1.36)_a^{***}$	$1.20 (1.32)_b$	$0.88 (1.73)_b$	$0.60 (1.22)_b$
Sadness	$0.33 (0.68)_a$	$0.48 (1.33)_a$	$5.88 (1.80)_b^{***}$	$0.40 (0.50)_a$
Happiness	$4.11 (1.31)_a^{***}$	$1.48 (1.42)_b$	$0.50 (0.72)_b$	$1.00 (1.29)_b$
Fear	$0.78 (1.91)_a$	$0.60 (1.32)_a$	$1.63 (1.97)_a$	$4.00 (1.44)_b^{***}$
Anxiety	$0.89 (1.89)_a$	$0.48 (1.33)_a$	$2.13 (2.19)_b$	$3.60 (2.10)_c^{***}$
Joy	$4.56 (1.67)_a^{***}$	$1.36 (1.41)_b$	$0.25 (0.44)_b$	$0.80 (1.63)_b$
Anger	$0.89 (1.69)_a$	$0.76 (1.30)_a$	$1.25 (1.11)_a$	$0.40 (0.87)_a$

Notes Subscript letters (a, b, c) indicate that the means are significantly different. $***p < 0.001$, $**p < 0.01$, $*p < 0.05$

Table 113.3 Time spent in solving the math line puzzle

Conditions	Time (SD)
Movie 1 ($N = 27$)	21.56 (9.09)
Movie 2 ($N = 25$)	16.96 (6.19)
Movie 3 ($N = 24$)	12.63 (8.59)
Movie 4 ($N = 25$)	13.60 (11.12)

Table 113.3 shows the results by experimental conditions. First, we conducted a one-way ANOVA to check whether there was a significant difference on the time spent on Math Line Puzzle between conditions. As expected, analysis revealed a significant main effect of the experimental conditions ($F(3, 97) = 5.28$, $p < 0.01$). Participants who watched Movie 1 spent significantly more time ($M_{\text{movie}}1 = 21.56$, SD = 9.09) than those who watched Movie 2 ($M_{\text{movie}}2 = 16.96$, SD = 6.19; $t(50) = 2.11$, $p < 0.05$). It meant that positive emotions induced by Movie 1 could effectively rebuild self-control after ego depletion. Participants who watched Movie 3 and 4 spent significantly less time ($M_{\text{movie}}3 = 12.63$, SD = 8.59; $M_{\text{movie}}4 = 13.60$, SD = 11.12) than those who watched Movie 2 ($M_{\text{movie}}2 = 16.96$, SD = 6.19; $t(49) = 2.03$, $p < 0.05$; $t(50) = 1.32$; $p < 0.10$). It revealed the inhibiting effect of negative emotions on self-control. Time spent on the Math Line Puzzle between Movie 3 and Movie 4 condition did not differ significantly ($t(49) = -0.34$, $p = 0.63$).

Moreover, since movie 3 and 4 were both used for priming negative emotions, we averaged the time in those two conditions ($M_{\text{movie}}3\&4 = 13.12$, SD = 9.87), and ran an ANOVA with the other two conditions. Again, results revealed a significant main effect on the time spent in Math Line Puzzle ($F(2, 98) = 7.92$, $p < 0.001$).

113.5 Conclusion

Self-control is a core concept in management, especially in consumer behavior. It is often considered as the critical factor of success. Higher self-control leads to purchases for long-term interest while lower self-control leads to more buying and more impulsive buying. An effective self-control, however, needs a large amount of psychological resources. Because individuals' inner resources are limited, it is difficult for them to exert self-control when the resources are largely depleted. When people are in the status of low psychological resources, they are prone to do damage to society or themselves, like alcoholism and aggressive behaviors [18, 19]. Therefore, it is crucial to find solutions for replenish psychological resources after ego depletion to rebuild individuals' self-control.

The current study posits that positive emotions have significant impacts on self-control after ego depletion. We test our hypothesis in a laboratory experiment. After an ego depletion task, participants were randomly assigned to watch one of the four movies aiming to induce positive, neutral or negative emotions. We found that compared to participants in the condition of neutral emotions, individuals in the condition of positive emotions showed higher self-control in the following task. On the contrary, participants primed by negative emotions showed lower self-control. The results suggest that positive emotions are an effective approach to offset the effect of ego depletion. Positive emotions could replenish individuals' psychological resources following ego depletion and rebuild self-control, whereas negative emotions restrain the replenishment of psychological resources and reduce self-control.

This study makes several contributions. First, it empirically demonstrates a causal relationship between positive emotions and self-control. We found that people who are primed by positive emotions after ego depletion show higher level of self-control. This adds to the growing literature on the positive emotions and the influence of positive emotions on consumer cognition and behavior. Second, we also compared the effects of different emotions. After an ego depletion task, individuals are also primed by negative emotions and neutral emotions respectively. We found that in comparison to people who watched the neutral clips, individuals primed by negative emotions show an inhibiting effect on self-control in the following task.

In addition to theoretical contributions, this research also has important managerial implications concerning management, especially in employee and consumer well-being. Employees and consumers are encountered ego depletion all the days. How to rebuild self-control in a short while after ego depletion becomes a critical issue for them. Employees have to deal with many assignments in their daily work and are more likely to feel exhausted in halfway. In this study, we find that positive emotions could replenish psychological recourses and help to rebuild self-control in a short time. Therefore, based on our findings, when employees encounter ego depletion in their work, companies could provide with some positive emotions stimuli, like provide some short funny videos for employees, which could help them to rebuild self-control in a short time and encourage them to finish the remaining work in high efficiency. Also for the employees themselves, they could also try to prime positive emotions by themselves, like try to memorize some happy moments or see some happy pictures, and rebuild higher self-control in the following tasks. Consumers also have the ego depletion problems. If they suffer ego depletion and experience lower self-control, they are more likely to make some unhealthy choices for short-term interest (like choose burger and chips for lunch instead of a healthy salad), or do some impulsive shopping. In those circumstance, we suggest employees to prime themselves with positive emotions, like think about some happy stories for a short while. By doing this, consumers would replenish their own psychological resources in a short time and enhance their self-control in the following purchase.

The current findings offer several avenues for further research. First, our study generally analyzed the impact of positive and negative emotions on self-control after ego depletion. Future research should also test whether there are differences between the effects of specific emotions (e.g. happiness, excited, love, surprise, etc.). Future work may employ other ways of manipulation [17] to induce specific emotion, and examine its impact on self-control. Second, Emotions are often divided into two main dimensions known as valence (meaning how positive or negative the experience is) and arousal (meaning the extent of reaction to stimuli). We have examined the valence dimension here; future research should address the arousal dimension. The appraisal tendency theory suggests that emotions could be divided on fine-grained level, for instance, pleasantness, responsibility, control, certainty, anticipated effort, legitimacy attentional activity, etc. [14, 16, 17]. It's rewarding to explore the effects of these dimensions as well. Finally, the current study conducted a laboratory experiment to test the effects of positive emotions on self-control after ego depletion. To add external validity to our results, we hope future research might use field experiments to generalize our findings to some realistic settings.

Acknowledgments This paper is supported by the Fundamental Research Funds for the Central Universities No. 2016JJ019 (Beijing Foreign Studies University) and Young Faculty Research Fund of Beijing Foreign Studies University No 2016JT003.

References

1. Ashby FG, Isen AM (1999) A neuropsychological theory of positive affect and its influence on cognition. Psychol Rev 106(3):529–550
2. Bargh A (1997) The automaticity of everyday life: advances in social cognition. Lawrence Erlbaum Associates, Mahwah
3. Bargh JA (1982) Attention and automaticity in the processing of self-relevant information. J Pers Soc Psychol 43(3):425–436
4. Bargh JA (1994) The four horsemen of automaticity:aAwareness, intention, efficiency, and control in social cognition. In: Basic processes, hand book of social cognition, pp 1–40
5. Baumeister RF (2002) Yielding to temptation: self-control failure, impulsive purchasing, and consumer behavior. J Consum Res 28(4):670–676
6. Baumeister RF, Bratslavsky E et al (1998) Ego depletion: Is the active self a limited resource? J Pers Soc Psychol 74(5):1252–1265
7. Drolet A, Mary F (2004) The rationalizing effects of cognitive load on emotion-based trade-off avoidance. J Consum Res 31:63–77
8. Ekman P, Freisen W, Ancoli S (1980) Facial signs of emotional experience. J Pers Soc Psychol 39(6):1125–1134
9. Feather N (1961) The relationship of persistence at a task to expectation of success and achievement related motives. J Abnormal Soc Psychol 63(3):552–561
10. Fredrickson B, Branigan C (2005) Positive emotions broaden the scope of attention and thought-action repertoires. Cogn Emotion 19(3):313–332
11. Fredrickson BL (2001) The role of positive emotions in positive psychology: the broaden and build theory of positive emotions. Am Psychol 56(3):218–226
12. Fredrickson BL, Levenson RW (1998) Positive emotions speed recovery from the cardiovascular sequelae of negative emotions. Cogn Emotion 12(2):191–220
13. Glass DC, Singer J, Friedman L (1969) Psychic cost of adaptation to an environmental stressor. J Pers Soc Psychol 12(3):200–210
14. Han S, Lerner J, Keltner D (2007) Feelings and consumer decision making: the appraisal-tendency framework. J Consum Psychol 17(3):158–168
15. Isen AM (2000) Some perspectives on positive affect and self-regulation. Psychol Inq 11(3):184–187
16. Isen AM, Means B (1983) The influence of positive affect on decision-making strategy. Soc Cogn 2(1):18–31
17. Isen AM, Johnson MM et al (1985) The influence of positive affect on the unusualness of word associations. J Pers Soc Psychol 48(6):1413–1426
18. Johnson KJ, Fredrickson B (2005) We all look the same to me' positive emotions eliminate the own-race bias in face recognition. Psychol Sci 16(11):875–881

19. Kivetz R, Itama S (2002) Self-control for the gence. J Consum Res 29:199–217
20. Lusardi A (2000) Explaining why so many households do not save. Harris School of Public Policy, University of Chicago, Photocopy
21. Muraven M, Elisaveta S (2003) Mechanisms of self-control failure: motivation and limited resources. Pers Soc Psychol Bull 29:894–906
22. Sniehotta F, Urte S, Ralf S (2005) Bridging the intention-behavior gap: planning, self-efficacy, and action control in the adoption and maintenance of physical exercise. Psychol Health 20(2):143–160
23. Vohs KD, Ronald J (2007) Spent resources: self-regulatory resource availability affects impulse buying. J Consum Res 33:537

Chapter 114
Impact Mechanism Study Between Sport Sponsorship Fit Degree and Brand Trust

Gaofu Liu and Minghua Jiang

Abstract In the sport sponsorship environment, the fit degree between sponsor brand and sponsored sport event is a core factor to promote consumer trust. In this thesis, the sport sponsorship consumers are the survey respondents. Based on comprehensive perspective, the impact mechanism model between fit degree and brand trust is built to make empirical test. In the study, it is found that the dimensions of fit degree have significant direct positive impact for sponsorship attitude and sponsor brand awareness. Sponsorship attitude has significant direct positive impact for brand competence, brand integrity and brand consistency. Except not having significant direct impact for brand integrity, sponsor brand awareness has significant direct positive impact for brand competence and brand consistency. Brand competence, brand integrity and brand consistency have significant direct positive impact for brand loyalty. Brand consistency plays the largest impact role for brand loyalty. In the above study, it is found that there is important theoretical guiding significance for sponsor to develop and optimize sponsorship marketing strategy.

Keywords Fit degree · Sponsorship attitude · Sponsor brand awareness · Brand trust · Brand loyalty

114.1 Introduction

The fit degree between sponsor brand and sponsored sport event is a key factor to impact corporate sponsorship effect. However, it is relatively insufficient for the previous research on this. Firstly, there is the relationship discussion among fit degree,

---

G. Liu (✉) · M. Jiang
Guanghua School of Management, Peking University,
Beijing 100871, People's Republic of China
e-mail: gaoyanzl@163.com

G. Liu
School of Business, Jiangxi Normal University,
Nanchang 330022, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_114

sponsorship attitude, sincerity perception, image transfer and brand familiarity in the current research [2, 10, 13, 14]. The relationship research between fit degree and consumer brand trust is lacked. Secondly, there is no literature for fit degree, which is divided into three sub-dimensions of function fit, reputation fit and image fit. There is no the relationship discussion between fit degree and brand trust, which is divided into three sub-dimensions of brand competence, brand integrity and brand consistency. Once again, a systematic theoretical framework is lacked to empirically test and explain mechanism and production process for fit degree to impact consumer brand trust. Sponsor is not told how to do a better job for sport sponsorship.

To compensate for the lack of these studies, this study adopts a comprehensive perspective to build a research framework among fit degree dimensions, sponsorship attitude, sponsor brand awareness and brand loyalty. This study systematically discusses what path and how fit degree impacts consumer brand trust in the sport sponsorship. Corporate sponsors will really know how fit degree can strategically promote consumer brand trust.

114.2 Hypothesis and Model Building

114.2.1 Fit Degree Impact for Sponsorship Attitude

Cornwell et al. [4] deemed that fit degree is matching, similarity or consistency based on "mission, product, market, technology, attribute, concept or any other relevance" between sponsor brand and sponsored sport event. Some researchers think that fit degree is a single dimension concept and is measured according to consumers' overall perception for sponsor brand and sponsored event. For more in-depth understanding and research for fit degree's rich connotation, Lafferty et al. [7] subdivided fit degree into product fit and brand fit. Lu [9] and Liu [8] thought that the matching between sponsor brand and sponsored event includes the three dimensions of market matching, product matching and brand matching. In fact, consumers' matching perception for sponsor brand and sponsored event may arise from different angles and has different dimensions. We deem that fit degree is one or some aspects matching degree between sponsor brand and sponsored event, including three dimensions of function fit, reputation fit and image fit.

Consumers' attitude towards sponsorship is their evaluation or emotion for sponsor brand and sponsored sport event. By this attitude, consumers evaluate the degree for liking or disliking a particular sponsored event. Olson [12] found that consumer's attitude towards sponsored event is more positive and sponsorship effect is better, if fit degree is higher in sponsored environment. Based on the above analysis, we propose the following hypotheses in order to explore how the different dimensions of fit degree could concretely impact sponsorship attitude in sport event sponsorship:

Hypothesis 1 (H1): Function fit has significant positive impact for sponsorship attitude.

Hypothesis 2 (H2): Reputation fit has significant positive impact for sponsorship attitude.

Hypothesis 3 (H3): Image fit has significant positive impact for sponsorship attitude.

114.2.2 Fit Degree Impact for Sponsor Brand Awareness

Brand awareness is consumer's ability to think of a certain brand in the specific episodic memory. It is made up of brand memory and brand recognition. When a certain brand type is given, brand memory is a capacity to remember a certain brand without any outside help. When a certain brand cue is given, brand recognition is a capacity to confirm a certain brand. The higher fit degree between sponsor brand and sponsored sport event could be more beneficial for consumers to deal with existing sponsor brand information and could be easier for consumers to approve actual behavior of sponsor brand and remember sponsor brand. Rifon et al. [15] found that sponsors having high fit degree are more altruistic, more acceptable and more reliable than those sponsors having low fit degree.

About image transfer, Zhang et al. [20] found that fit degree between sponsor brand and sponsored activity would actively impact sponsored activity image to transfer to sponsor brand. Pu's [14] research shows that fit degree between corporate sponsor and sponsored event is an important key element for consumers to respond to sponsorship behavior. Based on the above analysis, we propose the following hypotheses in order to explore how the different dimensions of fit degree could concretely impact sponsor brand awareness in sport event sponsorship:

Hypothesis 4 (H4): Function fit has significant positive impact for sponsor brand awareness.

Hypothesis 5 (H5): Reputation fit has significant positive impact for sponsor brand awareness.

Hypothesis 6 (H6): Image fit has significant positive impact for sponsor brand awareness.

114.2.3 Sponsorship Attitude Impact for Brand Trust

In the case of risk, brand trust is a functional willingness for consumers to believe that brand could fulfill its brand image and value. Delgado et al. [5] divided brand trust into the two dimensions of brand reliability and brand intention. Yuan [19] thought that brand trust is consumers' brand recognition willingness based on brand quality, behavioral intention and positive commitment expectation in the case of risk. He proposed that brand trust is made up of the three dimensions of quality trust, goodwill trust and competence trust. Xie and Peng [17] proposed that brand trust is made up of the three dimensions of competence, integrity and consistency. We believe that brand trust is consumers' confidence for brand competence, integrity and consistency in the uncertainty case. In addition, scholars generally believe that brand trust is a multidimensional concept, which is agreed with in this study. Xie and Peng's [17] approaches would be used for reference. Brand trust is divided into the three dimensions of brand competence, brand integrity and brand consistency.

Consumers' attitude towards sponsored event would impact communication effect of sponsor brand in sponsorship marketing. Zhang et al. [21] study shows that sport sponsorship attitude would impact consumers' purchase willingness for sponsor brand. Alexandris and his colleagues [1] found that positive sponsorship attitude would impact sponsor brand, sponsor reputation spread and purchase willingness. Therefore, we propose the following hypotheses:

Hypothesis 7 (H7): Sponsorship attitude has direct positive impact for brand competence.

Hypothesis 8 (H8): Sponsorship attitude has direct positive impact for brand integrity.

Hypothesis 9 (H9): Sponsorship attitude has direct positive impact for brand consistency.

114.2.4 Sponsor Brand Awareness Impact for Brand Trust

Brand awareness has an extremely important role in consumer behavior. On the one hand, consumers only decide their brand purchase after knowing brand. On the other hand, brand awareness would impact consumers' certain brand image formation. Consumers' good awareness for sponsor brand would provide a solid foundation and a strong driving force for consumers to trust sponsor brand. Sponsor brand awareness would impact consumers' confidence for sponsor brand. Consumers are more likely to trust their familiar and known sponsor brand. Chanavat's [3] study shows that consumers with good correlation and wonderful experience for sponsored event are more likely to trust sponsor brand. Therefore, we propose the following hypotheses:

Hypothesis 10 (H10): Sponsor brand awareness has direct positive impact for brand competence.

Hypothesis 11 (H11): Sponsor brand awareness has direct positive impact for brand integrity.

Hypothesis 12 (H12): Sponsor brand awareness has direct positive impact for brand consistency.

114.2.5 Brand Trust Impact for Brand Loyalty

Brand loyalty is consumers' favorite extent and repeated consumption for a certain brand. Brand loyalty is a key element in the existing brand equity model. Brand equity could perhaps be replaced, if brand loyalty is regarded as a one-dimensional concept. If consumers could win brand loyalty, trustworthy sense must firstly be won for brand by consumers. Delgado's [5] study also confirmed that brand trust would positively impact consumers' purchase intention and brand loyalty. Moliner et al. [11] found that transaction costs would be lower and consumers' brand loyalty level is higher, if consumers' brand trust level is higher. Therefore, we propose the following hypotheses:

Hypothesis 13 (H13): Brand competence has direct positive impact for brand loyalty.

Hypothesis 14 (H14): Brand integrity has direct positive impact for brand loyalty.

Hypothesis 15 (H15): Brand consistency has direct positive impact for brand loyalty.

114.2.6 Sponsorship Attitude Impact for Sponsor Brand Awareness

Sponsorship attitude is consumers' relatively long-lasting and overall assessment for sponsored event. In the sponsoring study, sponsorship attitude is one important factor to decide sponsorship effect. Positive attitude for sponsored event could induce consumers to transfer to sponsor brand image from sport event and consumers' acceptance for sport event actively impacts consumers' sponsor brand awareness. Therefore, we propose the following hypothesis:

Hypothesis 16 (H16): Sponsorship attitude has direct positive impact for sponsor brand awareness.

Based on the above analysis, we propose the following research model, as shown in Fig. 114.1.

114.3 Study Design

114.3.1 Variable Measurement

By the mature scales of fit degree, sponsorship attitude, sponsor brand awareness, brand trust and brand loyalty at home and abroad, the variable measurement items in this study are appropriately changed, adjusted and combined with the characteristics of consumers' culture environments and idiomatic expressions in China. Lu [9] and Liu's [8] measurement scale is used for reference in the fit degree questionnaire,

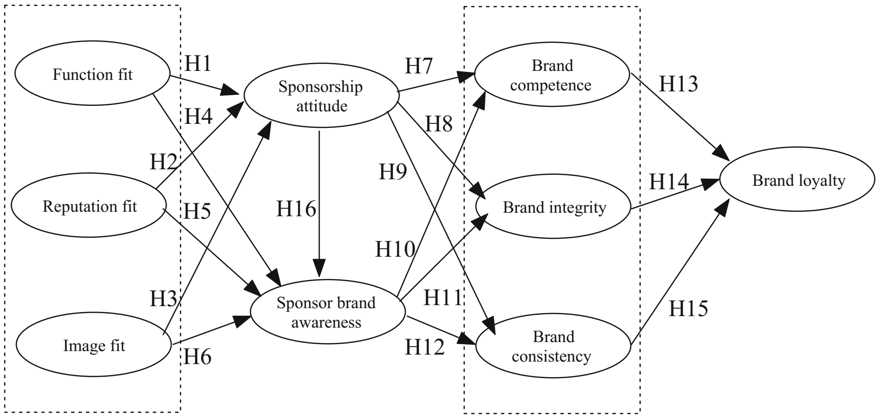


Fig. 114.1 The research hypothesis model

which is composed the eleven measurement items. Olson's [12] measurement scale is used for reference in the sponsorship attitude questionnaire, which is composed of the four items. Mao's [10] measurement scale is used for reference in the sponsor brand awareness questionnaire, which is composed of the three items. Xie and Peng's [17] measurement scale is used for reference in the brand trust questionnaire, which is composed of the ten items. Yi's [18] measurement scale is used for reference in the brand loyalty questionnaire, which is composed of the four items. Likert's measurement scale of seven point type is adopted in the all measurement items.

114.3.2 Study Sample

Currently, Beijing and Shanghai are the two major areas for sporting events. In Beijing and Shanghai, there are a variety of sporting events, event sponsorships are frequent, visitors are more and quality is high. Therefore, we issue the questionnaires in Beijing and Shanghai in order to facilitate sampling. The questionnaire is carried through the combination of online research and offline research. There are online and offline 1000 questionnaires totally. 836 are returned and 613 are valid. The descriptive statistics of the valid questionnaires is shown in Table 114.1

Table 114.1 Descriptive statistics of study sample

Statistical variables	Sample distribution
Gender	59.2 % is for men and 40.8 % is for women.
Age	0.5 % is under 20 years, 25.3 % is between 21 years and 30 years, 29.4 % is between 31 years and 40 years, 27.1 % is between 41 years and 50 years, and 17.7 % is more than 51 years
Educational background	6.2 % is for high school or less, 15.6 % is for technical secondary school and junior college, 53.7 % is for undergraduate and 24.5 % is above bachelor.
Monthly income	0.9 % is below 3,000 Yuan, 12.5 % is between 3001 Yuan and 3,999 Yuan, 13.6 % is between 4001 Yuan and 4,999 Yuan, 21.8 % is between 5001 Yuan and 5999 Yuan, and 51.2 % is more than 6,001 Yuan.
Employer	15.8 % is for foreign-funded enterprise, 6.9 % is for government sector, 23.1 % is for public institution, 2.1 % is for state-owned enterprise, 47.3 % is for private enterprise and 4.8 % is for others.

114.4 Analysis Result

114.4.1 Scale Reliability and Validity Test

(1) Reliability Test

In this thesis, the confirmatory factor analysis is used to test the measurement model, including the internal consistency test and the convergent validity test. The reliability is measured with the composite reliability (C.R.) and Cronbach's Alpha value. In Table 114.2, it can be seen that the C.R. values of the all variables are larger than the recommended value 0.7 and Cronbach's Alpha values of the all variables are also larger than the critical value 0.7. These indicate that there is the higher internal consistency for the sample data and the reliability is good.

(2) Validity Test

Validity is a trait degree for measurement tools to measure mentality or behavior, including convergent validity and discriminant validity. Average Variance Extracted value (AVE value) can be used to test convergent validity and discriminant validity of each potential variable. Convergent validity is a correlation degree to measure same dimension among different items. If Average Variance Extracted value (AVE value) is greater than 0.5, this indicates that measurement items could explain factors' variance above 50 % to show that the latent variable has good convergent validity [16]. In each study facet, the AVE value test results are shown in Table 114.2. The AVE values of each study facet are between $0.6014 \sim 0.7923$ and are higher than the minimum standard value 0.5. These indicate that there could be better convergent validity in each study facet.

Table 114.2 Confirmatory factor analysis results, C.R and Cronbach's Alpha value

Study facet	Measuring item	Standardized factor loading	T value	AVE	C.R.	Cronbach's Alpha value
Function fit	FF1	0.86	–	0.7025	0.9041	0.9003
	FF2	0.88	36.245			
	FF3	0.8	31.92			
	FF4	0.81	35.433			
Reputation fit	RF1	0.86	–	0.7806	0.9143	0.9081
	RF2	0.9	44.666			
	RF3	0.89	41.192			
Image fit	IF1	0.88	–	0.7622	0.9276	0.9206
	IF2	0.9	46.1			
	IF3	0.89	43.741			
	IF4	0.82	38.013			
Sponsorship attitude	SA1	0.74	–	0.6014	0.8577	0.8508
	SA2	0.79	26.645			
	SA3	0.81	27.491			
	SA4	0.76	25.477			
Sponsor brand awareness	SBA1	0.88	–	0.7923	0.9196	0.9103
	SBA2	0.91	44.85			
	SBA3	0.88	42.262			
Brand competence	BCM1	0.85	–	0.6554	0.85	0.8416
	BCM2	0.86	31.977			
	BCM3	0.71	26.198			
Brand integrity	BI1	0.85	–	0.7339	0.8922	0.8893
	BI2	0.86	36.411			
	BI3	0.86	36.107			
Brand consistency	BCN1	0.74	–	0.6019	0.8579	0.8504
	BCN2	0.82	27.012			
	BCN3	0.8	29.644			
	BCN4	0.74	27.116			
Brand loyalty	BL1	0.79	–	0.6091	0.8608	0.8567
	BL2	0.87	31.489			
	BL3	0.77	30.11			
	BL4	0.68	25.547			

Table 114.3 Comparison between correlation coefficient matrix and square root of extracted average variance

	1	2	3	4	5	6	7	8	9
Function fit	0.84								
Reputation fit	0.47	0.88							
Image fit	0.48	0.49	0.87						
S-attitude	0.42	0.46	0.49	0.78					
SB-awareness	0.55	0.39	0.34	0.51	0.89				
B-competence	0.45	0.34	0.32	0.48	0.43	0.81			
B-integrity	0.44	0.34	0.34	0.43	0.44	0.36	0.86		
B-consistency	0.49	0.37	0.36	0.39	0.4	0.42	0.36	0.77	
Brand loyalty	0.38	0.3	0.29	0.41	0.38	0.39	0.48	0.46	0.78

Note The ones above the diagonal are the square roots of the AVE, the left ones below the diagonal are the correlation coefficients of each variable

Discriminant validity is a trait difference degree to measure different concept items. Fornell and Larcker [6] suggest that this measurement model has good discriminant validity, when AVE value's square root is greater than the correlation coefficient between AVE value and other latent variables [6]. To test the discriminant validity of each study facet, this study gathers the AVE value's square root and the correlation coefficient between this variable and other variables. The results have been shown in the following Table 114.3. Wherein, the numbers above the diagonal are the square roots of each variable AVE value. The ones below the diagonal are the correlation coefficient between each variable and other variables. From the results in Table 114.3, the AVE value's square root in each study facet is significantly larger than the correlation coefficient between AVE value and other latent variables. This indicates that there is good discriminant validity among study facets and there is necessity for independent existence.

114.4.2 Research Hypothesis Testing

In this thesis, the structural equation modeling is adopted to test the rationality of the theoretical model. The fit degree dimension is the exogenous variable. Sponsorship attitude, sponsor brand awareness, brand competence, brand integrity, brand consistency and brand loyalty are the endogenous variables. The relationships among the latent variables are investigated. The test results of the research hypotheses are shown in Table 114.4. The model fitting indexes are $\chi^2/df = 2.176$, $GFI = 0.902$, $AGFI = 0.916$, $RMSEA = 0.064$, $NFI = 0.921$, $RFI = 0.913$, $IFI = 0.919$, $TLI = 0.908$ and $CFI = 0.917$. From the fitting indexes, RMSEA value is slightly higher than the conservative recommended value 0.05 and it is less than the acceptable value

Table 114.4 Structural equation model results

Null hypothesis	Path relationship	Standardized path coefficient	T value	P	Conclusion
H1	Function fit → Sponsorship attitude	0.67	26.886	***	Support
H2	Reputation fit → Sponsorship attitude	0.61	26.646	***	Support
H3	Image fit → Sponsorship attitude	0.62	19.739	***	Support
H4	Function fit → Sponsor brand awareness	0.13	5.348	***	Support
H5	Reputation fit → Sponsor brand awareness	0.12	4.359	***	Support
H6	Image fit → Sponsor brand awareness	0.12	4.876	***	Support
H7	Sponsorship attitude → Brand competence	0.3	8.338	***	Support
H8	Sponsorship attitude → Brand integrity	0.56	13.918	***	Support
H9	Sponsorship attitude → Brand consistency	0.5	12.879	***	Support
H10	Sponsor brand awareness → Brand competence	0.43	12.002	***	Support
H11	Sponsor brand awareness → Brand integrity	0.07	1.897	0.58	Not support
H12	Sponsor brand awareness → Brand consistency	0.23	6.571	***	Support
H13	Brand competence → Brand loyalty	0.11	3.374	***	Support
H14	Brand integrity → Brand loyalty	0.26	8.59	***	Support
H15	Brand consistency → Brand loyalty	0.45	13.277	***	Support
H16	Sponsorship attitude → Brand awareness	0.56	10.81	***	Support

Note * indicates $P < 0.05$, ** indicates $P < 0.01$ and *** indicates $P < 0.001$

0.08. The other indexes all reach the standard recommended value to indicate that the model fitting conditions in this study are good.

From the test results in Table 114.4, the rest hypotheses have all passed the significance test, in addition to H11 not passing the significance test. In this regard, (1) each dimension of fit degree has significant direct positive impact for sponsorship attitude. From the impact path coefficients of the various dimensions for sponsorship attitude, function fit has the largest impact for sponsorship attitude (the path coefficient is 0.67), image fit takes the second place (the path coefficient is 0.62) and reputation fit is the least one (the path coefficient is 0.61). (2) Each dimension of fit degree has significant direct positive impact for sponsor brand awareness. From the impact path coefficients of the various dimensions for sponsor brand awareness, function fit has the largest impact for sponsor brand awareness (the path coefficient is 0.13). Image fit and reputation fit take the second places (the path coefficients are both 0.12). (3) Sponsorship attitude has significant direct positive impact for brand competence, brand integrity and brand consistency. Thereinto, there is the greatest impact for brand integrity (the path coefficient is 0.56), there is the second impact for brand consistency (the path coefficient is 0.50) and there is the least impact for brand competence (the path coefficient is 0.30). This indicates that sponsorship attitude plays an important intermediary role in fit degree's impact for brand trust. (4) In addition to not passing the significance test for brand integrity, sponsor brand awareness has significant direct positive impact for brand competence and brand consistency. But there is the greater impact for brand competence (the path coefficient is 0.43) and there is the second impact for brand consistency (the path coefficient is 0.23). In addition, from sponsorship attitude and sponsor brand awareness impact for three dimensions of brand trust, it is found that sponsorship attitude has the greater direct positive impact for three dimensions of brand trust. This indicates that sponsorship attitude is the more important antecedent variable for brand trust than sponsor brand awareness. (5) Brand competence, brand integrity and brand consistency all have significant direct positive impact for brand loyalty. Brand consistency has the greatest impact for brand loyalty (the path coefficient is 0.45), brand integrity takes the second place (the path coefficient is 0.26) and brand competence has the least (the path coefficient is 0.11).

114.5 Conclusion and Implication

114.5.1 Conclusion

In this thesis, sport sponsorship consumers are the research sample to establish the impact mechanism model between fit degree dimension and consumer brand trust. The empirical analysis is carried out. In the study, it is found that (1) each dimension of fit degree has significant direct positive impact for sponsorship attitude and sponsor brand awareness. Each dimension of fit degree is helpful to improve consumers' attitude for sponsorship and brand awareness for sponsor. In addition, in the dimensions of fit degree, function fit has the greatest impact for sponsorship attitude and sponsor brand awareness. Image fit takes the second place and reputation fit has the least. (2) Sponsorship attitude has significant direct positive impact for brand competence, brand integrity and brand consistency. Thereinto, there is the greatest impact for brand integrity. There is the second impact for brand consistency. There is the least impact for brand competence. (3) In addition to not passing the significance test for brand integrity, sponsor brand awareness has significant direct positive impact for brand competence and brand consistency. However, there is the greater impact for brand competence. There is the second impact for brand consistency. (4) Brand competence, brand integrity and brand consistency all have significant direct positive impact for brand loyalty. Brand consistency has the greatest impact for brand loyalty. Brand integrity takes the second palace. Brand competence has the least.

114.5.2 Management Implication

The first, when enterprises choose sponsored sport events, fit degree between sponsor brand and sport event should be assessed to seek and create the best conjunction point. Because sport sponsorship has good results for corporate brand marketing, a lot of enterprises would treat sport event sponsorship as an important means for corporate brand marketing. In the selection of sponsorship sport events, effective fit degree assessment is lacked to blindly sponsor and there is a huge risk for business operation. Therefore, when sponsoring sport event, enterprises should scientifically assess fit degree between sponsor brand and sport event, and firstly seek functionality between sponsor brand and sponsored sport event and then fit degree between image and reputation. Finally, superior resources are concentrated to build a conjunction point of certain "natural" or "artificial" functionality, image and reputation between sponsor brand and sponsored sport event.

The second, corporate sponsors should pay attention to consumer attitude for sponsorship and monitor consumer situation for sponsor brand awareness. This study shows that sponsorship attitude plays an important intermediary role in fit degree impact for sponsor brand awareness and brand trust. Therefore, enterprises should more reflect corporate social responsibility, be in favor of altruistic development motive of sponsored sport event, avoid excessive commercialization and pay attention to consumer attitude evaluation for corporate sponsored sport event. In addition, for sponsorship attitude, sponsor brand awareness is also an important antecedent variable to promote consumer brand trust. Therefore, corporate sponsors should use the advanced market research methods and measurement tools to timely monitor consumer situation and detect consumer changing trend for sponsor brand awareness. Scientific methods are used to intervene and improve consumer cognition and memory for sponsor brand awareness.

The third, corporate sponsors need to establish consumer confidence for brand competence, brand integrity and brand consistency, especially for consumer confidence for brand consistency. This study shows that consumer confidence for corporate sponsor's brand consistency is the most important antecedent variable for consumer brand loyalty. In fact, when consumers like and enjoy a certain sport event to have recognition and satisfaction for sponsor brand, this favorable impression could likely be transferred from sport event to sponsor brand to form good emotional relationship and eventually generate loyalty for sponsor brand. Therefore, corporate sponsors need to maintain the consistency image for sponsor brand appeal, continue to carry out long-term sponsorship, create more opportunities for emotional appeal and communication, and promote consumers to generate loyalty for sponsor brand.

Acknowledgments This paper is supported by National Natural Science Foundation of China (71172030).

References

1. Alexandris K, Tsaousi E, James J (2007) Predicting sponsorship outcomes from attitudinal constructs: the case of a professional basketball event. Sport Mark Q 16(3):130–139
2. Bruhn M, Holzer M (2015) The role of the fit construct and sponsorship portfolio size for event sponsorship success: a field study. Eur J Mark 49(5/6):874–893
3. Chavanat N, Martinent G, Ferrand A (2009) Sponsor and sponsees interactions: effects on consumers' perceptions of brand image, brand attachment, and purchasing intention. J Sport Manag 23(5):644–670
4. Cornwell TB, Humphreys MS et al (2006) Sponsorship-linked marketing: the role of articulation in memory. J Consum Res 33(3):312–321
5. Delgado-Ballester E, Luis Munuera-Alemán J (2005) Does brand trust matter to brand equity? J Prod Brand Manag 14(3):187–196
6. Fornell C, Larcker DF (1981) Structural equation models with unobservable variables and measurement error: algebra and statistics. J Mark Res pp 382–388
7. Lafferty BA (2007) The relevance of fit in a cause-brand alliance when consumers evaluate corporate credibility. J Bus Res 60(5):447–453
8. Liu Y (2014) Scaling and validity analysis of sport event sponsorship match. Sport Sci Res 35(3):15–20
9. Lu CB (2009) The selection between match and sport sponsorship event: an empirical study based on brand equity. Sport Sci 29(8):82–89
10. Mao LL, Zhang JJ (2013) Impact of consumer involvement, emotions, and attitude toward beijing olympic games on branding effectiveness of event sponsors. Sport Bus Manag: Int J 3(3):226–245
11. Moliner MA, Sánchez J et al (2007) Perceived relationship quality and post-purchase perceived value: an integrative framework. Eur J Mark 41(11/12):1392–1422
12. Olson EL (2010) Does sponsorship work in the same way in different sponsorship contexts? Eur J Mark 44(1/2):180–199
13. Papadimitriou D, Kaplanidou K, Papacharalampous N, Johnston W, Johnston W (2016) Sport event-sponsor fit and its effects on sponsor purchase intentions: a non-consumer perspective among athletes, volunteers and spectators. J Bus Ind Mark 31(2):1–44
14. Pu Y (2014) Difference fit strategy: three sponsors multiple cases study discovery based on 2012 London Olympics. Sport Sci 34(4):58–69
15. Rifon NJ, Choi SM et al (2004) Congruence effects in sponsorship: the mediating role of sponsor credibility and consumer attributions of sponsor motive. J Advert 33(1):30–42

16. Wu ML (2009) A study on measurement of health utility value. Chongqing University Press, Chongqing (in Chinese)
17. Xie Y, Pang SQ (2009) Brand trust impact for the relationship between consumer and brand: dimension level analysis. J Mark Sci 5(3):1–25
18. Yi Y, Jeon H (2003) Effects of loyalty programs on value perception, program loyalty, and brand loyalty. J Acad Mark Sci 31(3):229–240
19. Yuan DH (2007) Context and prospect of brand trust research. Psychol Sci 30(2):434–437
20. Zhang L, Lin S, Fan TT (2007) Image transfer factors between sponsored event and sponsorship brand - an empirical study based on sponsored super girl of mengniu sour milk. Manag World 7:84–93 (in Chinese)
21. Zhang Z, Won D, Pastore DL (2005) The effects of attitudes toward commercialization on college students' purchasing intentions of sponsors' products. Sport Mark Q 14(3):177–187

Chapter 115
Resource Conflict Identification-Resolution-Based Construction Temporary Facilities Layout Framework in a Dam Construction Project

Xiaoling Song, Rui Qiu, Charles Shen and Feniosky Peña-Mora

Abstract Construction temporary facilities (CTF) layouts are important in large-scale or mega construction projects, if planned well, are expected to save cost, enhance construction quality and develop operation efficiency. Planning an efficient CTF layout requires the prevention of resource conflicts with other important pre-planning tasks. This paper starts from a specific dam construction project to identify potential conflicts, analyze root causes and their mutual relationships. Based on the identified conflicts and the basic conflict management mechanism, a CTF layout framework is proposed to finalize a CTF layout alternative with the least conflicts between the CTF layout and other pre-planning tasks. By using the framework, a CTF layout is able to be obtained for the specific dam construction project.

Keywords Resource conflict · Conflict identification · Conflict resolution · CTF layout

115.1 Introduction

Construction temporary facilities (CTFs) are widely used in large-scale or mega projects to support construction processes and will be removed after completion. For open-environment construction projects, such as the dam construction project for hydropower station project, the most used CTFs include labor residences, integrated

X. Song (✉)
School of Economics & Management, Nanjing University of Science and Technology,
Nanjing 210094, People's Republic of China
e-mail: songxiaoling426@163.com

X. Song · R. Qiu
Uncertainty Decision-Making Laboratory, Sichuan University,
Chengdu 610064, People's Republic of China

X. Song · C. Shen · F. Peña-Mora
Advanced ConsTruction and InfOrmation TechNology (ACTION) Laboratory,
Department of Civil Engineering and Engineering Mechanics,
Columbia University, New York, NY 10027, USA

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_115

warehouses, offices, construction substations, storage depots, and water supply stations etc. In this context, the CTF layout refers to locate CTFs at suitable pre-identified locations with the aim of optimizing construction processes [1]. An efficient layout is assumed to contribute greatly to the operational efficiency, cost, and quality of construction. The CTF layouts are commonly planned before actual operations, thus, many issues that may take place in practical construction operations should be taken into account for a better CTF layout selection in advance.

Project owners have responsibilities to deal with issues that are related to site acquisition, financing and other crucial conditions in most large-scale or mega construction projects. The general contractors are responsible for project owners, who are in charge of almost everything else, and subcontractors would often bid for implementing highly specialized sub-projects for general contractors, such as hazmats transportation, raw material supply, and tunnel excavation [2]. In practice, the general contractor and subcontractors have to draft plans for their future construction operations. For example, in a specific dam construction project in this paper, the general contractor needs to conduct the task of planning a CTF layout for constructions based on his/her own knowledge and expertise. In the current literature review, much research has been carried out to assist the general contractor for satisfactory CTF layout based on problem-specific constraints [3–6]. All these research has focused on resolving specific CTF layout-related difficulties and practical problem-specific constraints. However, when discussing CTF layouts from these existing methods in a moderator meeting, which is established in construction projects to achieve a balanced solution that is possible for all stakeholders to accept by considering their own tasks, many conflicts arise among involved parties and this topic attracts our great interest in our current research on CTF layout planning.

Conflicts are common when the involved general contractors and subcontractors are optimizing their pre-planning tasks since they may need the same resource (e.g. space, workforce) at the same time, if left unresolved, can have adversarial effects on the progress of a project. In this paper, conflicts refer to any actions or circumstances that are resulted from incompatible or opposing needs [7, 8]. Current research has suggested that resolving conflicts for general contractors and subcontractors is crucial in construction projects [9]. Many serious accidents took places due to the fact that conflicts were not resolved according to the Ministry of Housing and Urban-Rural Development, P.R. China. Nevertheless, Conflict issues were ignored in the CTF layout research, and taking the conflicts among involved stakeholders into consideration becomes quite crucial for the general contractor to achieve a CTF layout.

115.2 Research Motivation and Approach

Our research on designing CTF layouts based on the resource conflict identification and resolution aims to tackle the layout-related practical challenges of large-scale or mega construction projects. The motivation behind this particular research is to identify and resolve potential resource conflicts between the CTF layout and other pre-planning tasks. At the same time, a CTF layout with the least conflicts is able to be obtained for the specific general contractor or subcontractor. We are planning to finish this research in four steps: (1) obtaining CTF layout alternatives and plans of other pre-planning works based on our previous work; (2) conducting on-the-spot investigations and surveys to identify the different types of resource conflicts related to CTF layouts, to analyze the potential causes of these conflicts, and to understand the conflict management mechanism; (3) suggesting a framework to resolve as many potential conflicts as possible for a better CTF layout and other pre-planning tasks; (4) proposing and implementing appropriate use cases to test if the framework works well.

However, this paper is only targeted at the second and third phases of the research to have a conceptual framework for obtaining an ultimatum CTF layout which has the least conflicts with other pre-planning tasks for a specifical dam construction project. A large amount of practical investigations and surveys are conducted and questionnaires are collected from involved engineers and experts to identify potential resource conflicts between the CTF layout and other pre-planning tasks. Statistics analysis tools are applied to categorize those conflicts and theoretical modelling is adopted to identify the conflict management mechanism, which provide a basis for the following conflict resolution-based CTF layout framework for a specific dam construction project.

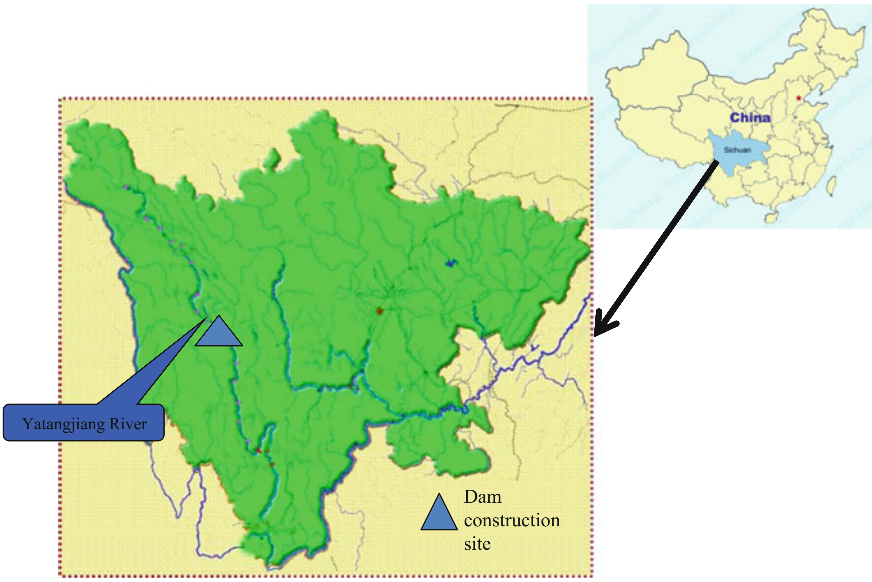


Fig. 115.1 The geographical location of the dam construction project

115.3 Project Brief and Problem Statement

The hydropower station lies in a bend of the Yalong River in Sichuan Province, China, as geographically shown in Fig. 115.1. The construction began in 2005 and the expected generation capacity is 6×600 MW after a successful completion. Constructing dams for hydropower station projects is complex as it is related to many construction issues, such as the CTF layout, the relocation of the nearby residents, and the resource scheduling. When we are doing the on-the-spot investigations and surveys, it is quite hard to design the CTF layout and finish other construction processes due to the project's typical geo-characteristics, for example, it is planned in deep valleys, steep bank slopes, and exposed bedrock.

In practical situations, the general contractor attempts to plan a CTF layout to facilitate related construction processes. Since the CTF layout is an intricate task, the general contractor often implements it based on their previous experience, ad-hoc rules, common sense, and adaptation of past layouts to the present project. Reference [3] proposed a GIS-based approach to identify feasible locations for CTFs based on geographical characteristics [3], applied CAD-aided tools [10], and [1] used mathematical techniques for layout objective optimizations. In the context, decision options for the CTF layouts are obtained based on the method from [1] for the general contractor.

Apart from the CTF layout, plans for other pre-planning tasks are also conducted by other general contractor and subcontractors before the beginnings of actual construction operations. Each general contractor or subcontractor attempts to achieve the respective solutions under the circumstances that they will have access to all resources (e.g. labor, routes, space) whenever they need. Under these circumstances, conflicts are often resulted due to the incompatible needs or actions for project objectives, quality requirements, schedule plans, project costs, technical issues, management procedures and resource assignment etc. If the conflicts are not controlled or prevented in advance, the construction efficiency, the construction costs, the risks of construction operations and the construction quality are likely to be negatively affected. It is reflected from the practical investigations that only a small number of the involved experts and engineers agree that win-win or multi-win objectives can be expected. Since the construction operations are about transforming different types of resources (e.g. human resources, physical resources, time resources and information resources etc.), our research is conducted based on identify and resolve potential resource conflicts. Much research has been studied to discuss potential resource conflicts in the construction projects [11–13]. Based on some resource conflict literature and practical investigations, potential conflicts between the CTF layout and other pre-planning tasks in our dam construction project are identified and analyzed in the following Sect. 115.4.

115.4 Resource Conflict Identification Between the CTF Layout and Other Pre-Planning Tasks

In the specific construction project, 6 Pareto CTF layout alternatives (as shown in Fig. 115.2) are obtained for 15 CTFs (as shown in Table 115.1) using our previous method from [1]. At the same time, different solutions for other pre-planning tasks are obtained from those in-charge subcontractors, who generate solutions based on their experiences and existing methods. Finally, conflicts between the CTF layout and 5 pre-planning tasks are considered in this paper, including 6 decision options for the plan of material; 4 decision options for the plan of equipment; 4 decision options for the plan of transport routes; 5 decision options for the plan of hazmats transportation, and 4 decision options for the plan of workforce (shown in Fig. 115.3). It is noted that since this paper focuses on obtaining a CTF layout for the general contractor, the conflicts between the CTF layout and the 5 pre-planning tasks are considered, however, the conflicts among different subcontractors are neglected (as shown in Fig. 115.3). Under these circumstances, there are $5 \times 6 \times 4 \times 4 \times 5 \times 4 = 9600$ alternatives for the construction project and this study aims to identify conflicts between the CTF layout and the 5 pre-planning tasks in each alternative, and select the alternative with the least conflicts.

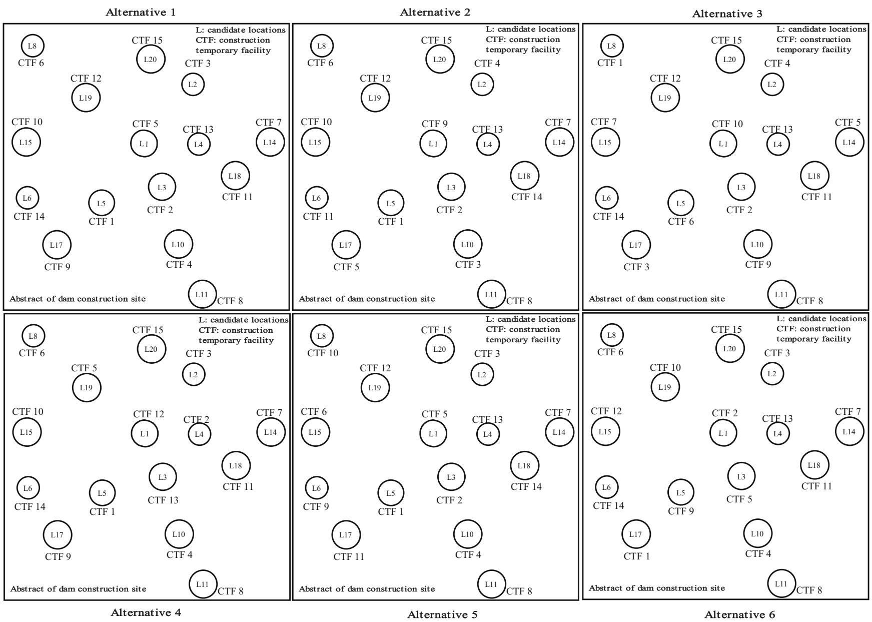


Fig. 115.2 The CTF layout alternatives for the specific dam construction project

Table 115.1 CTFs for the dam construction project

Facilities	CTF 1	CTF 2	CTF 3	CTF 4	CTF 5	CTF 6	CTF 7	CTF 8
Facility	Labor	Office	Warehouse	Steel	Rebar	Explosive	Stone	Oil depot
item	residence			storage	storage	storage	and sand	
Facilities	CTF 9	CTF 10	CTF 11	CTF 12	CTF 13	CTF 14	CTF 15	
Facility	Mental	Maintenance	Equipment	Concrete	Carpentry	Reinforcing	Drill tools	
item	installing	shop	repair	shop	shop	steel shop	repair	

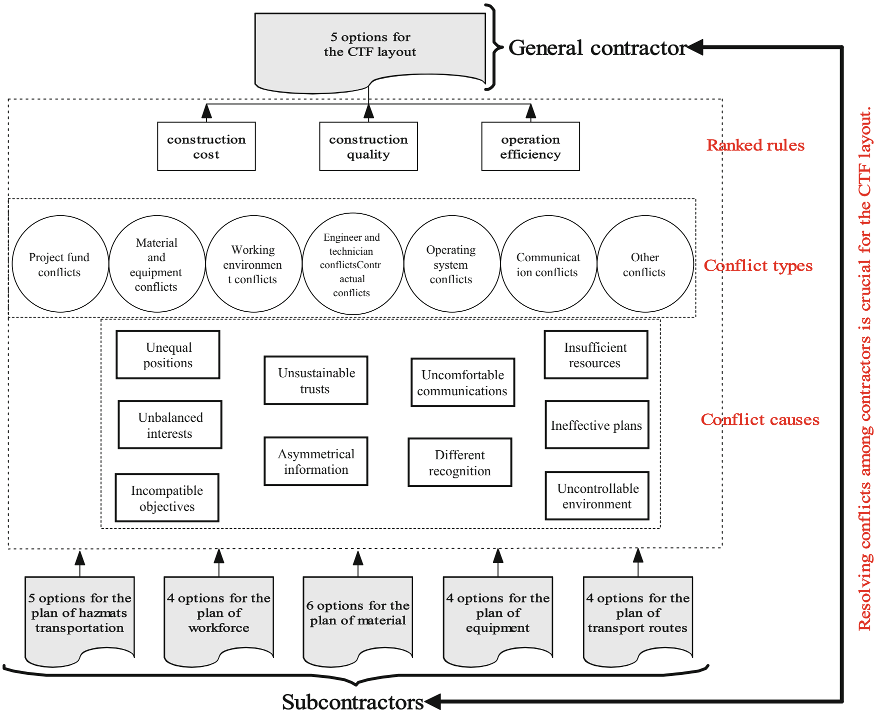


Fig. 115.3 The general contractor-subcontractors structure in the dam construction project

115.4.1 Resource Conflict Types

Many industry professionals and researchers categorize conflicts based on practical projects [8, 14]. In this study, the conflicts are classified according to the resource types in the specific dam project. The resource conflicts are categorized into seven types based on the practical investigations (as shown in Table 115.2), including project fund conflicts (Type I), material and equipment conflicts (Type II), working environment conflicts (Type III), engineer and technician conflicts (Type IV), operating system conflicts (Type V), communication conflicts (Type VI) and other conflicts (Type VII). If these conflicts are not pre-considered when finalizing the

Table 115.2 Resource conflict types between CTF layout and other pre-planning tasks

No	Conflict types	Conflict descriptions
I	Project fund conflicts	Short of fund, or unable to guarantee on-time payment, having a negative impact on purchasing raw materials or other fund-related works.
II	Material and equipment conflicts	Unable to supply materials on time, lack of installation equipment, the material supply and demand being incompatible or the provided and required equipment being incompatible, presenting a negative on material-related or equipment-related works.
III	Working environment conflicts	Unable to open up some construction operations simultaneously due to the fact that the space is restricted, being conflicting in economic interests or schedules.
IV	Engineer and technician conflicts	Lack of communications between technicians and management staff, the managers being unable to supervise construction operations in a right way, or the technicians not being equipped with new techniques.
V	Operating system conflicts	Have outdated or damaged machines, thus some operation requirements cannot be met.
VI	Communication conflicts	Confront many difficulties in communication among general contractors and subcontractors, causing a low efficiency.
VII	Other conflicts	Experience unpredictable weather, accidents, un-finished preparations.

ultimatum CTF layout for the general contractor, conflicts are about to take place in the future works and impact the practical construction operations negatively.

115.4.2 Conflict Causes

In the dam construction project, all general contractors and subcontractors work under contracts, which prescribe rights, duties, profits and risks for different stakeholders. However, incompatible needs and requirements are commonly generated in practical construction, resulting many conflicts between involved stakeholders. Causes for resource conflicts have been widely discussed in current literature, which mainly include unequal positions, incompatible objectives, unbalanced interests, asymmetrical information, insufficient resources, uncomfortable communications, unsustainable trusts, different recognition, ineffective plans and uncontrollable environment. They are root causes for resource conflicts between the CTF layout and other pre-planning tasks.

According to our practical investigations, these root causes are not independent. For example, the incompatible objectives between the CTF layout and the transport routes planning are likely to lead to uncomfortable communications. Consequently,

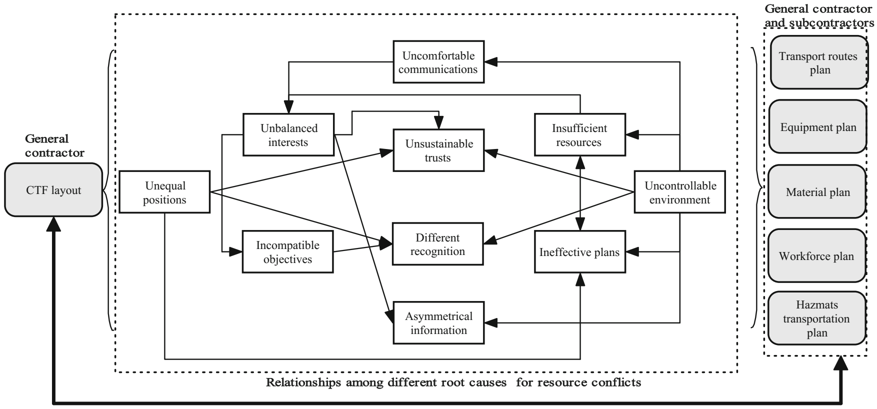


Fig. 115.4 The relationships among different root causes

the relationships among different root causes are summarized in Fig. 115.4 between the CTF layout and other pre-planning tasks.

115.5 Conflict Resolution-Based CTF Layout Framework

Although there are different types of resource conflicts with various root causes between the CTF layout and 5 other pre-planning tasks, identifying the basic conflict management mechanism would be quite helpful to control or resolve possible conflicts. For example, if the conflict management mechanism is identified, we can apply different methods to resolve the conflicts in different stages. Although this paper aims to select the CTF layout with the least conflicts from 9600 alternatives, understanding the conflict management mechanism in Fig. 115.5 would be helpful for practical conflict prevention, control and resolution. Under these circumstances, a framework is proposed to guide the general contractor to achieve the CTF layout. The main components of the proposed framework is roughly described.

115.5.1 Component I: Fuzzy Group AHP

The conflicts identification-resolution based CTF layout framework is transformed into a selection of the compromise resolution that has the least conflicts with other tasks based on the ranked rules (e.g. construction costs, construction quality and operation efficiency). This problem is abstracted as a multiple attributes group decision making (MAGDM) problem. The parties involved in these pre-planning tasks include A/E engineering, general contractors, subcontractors, and superintendents.

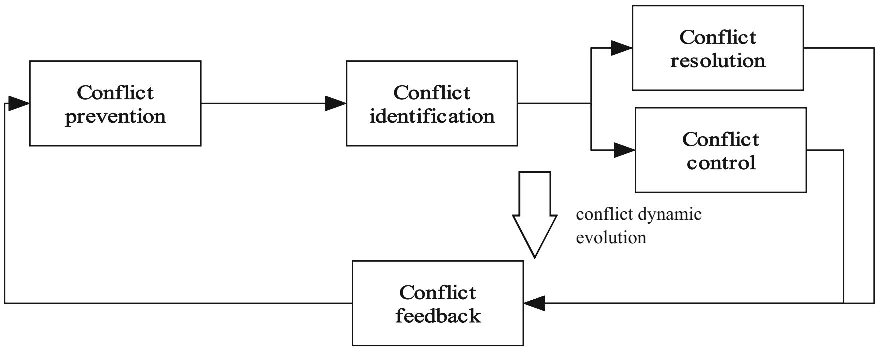


Fig. 115.5 The relationships among different root causes

In the specific dam construction project, the moderate group is composed of 10 members.

We assume that the decision makers $DM^1, DM^2, \cdots, DM^{10}$ would choose the best among the 9600 alternative solutions (denoted as x) under 3 attributes "construction costs, construction quality and operation efficiency", denoted as "ATT_1" "ATT_2"and "ATT_3". First, each decision maker DM^z provides their judgements, and a decision matrix Π^z_{xy} for each alternative solution with respect to the attributes ATT_y. The π^z_{xy} is the preference value for the alternative x with respect to ATT_y given by DM^z. The decision matrix Π^z_{xy} is obtained as Eq. (115.1):

$$\Pi^z_{xy} = \begin{pmatrix} \pi^z_{11} & \pi^z_{12} & \pi^z_{13} \\ \vdots & \vdots & \vdots \\ \pi^z_{x1} & \pi^z_{x2} & \pi^z_{xY} \\ \vdots & \vdots & \vdots \\ \pi^z_{9600-1} & \pi^z_{9600-2} & \pi^z_{9600-3} \end{pmatrix}. \tag{115.1}$$

115.5.2 Component II: Elimination Method

Resource conflicts in construction operations are often complex with many decision makers, constraints, and possible solutions. Under these circumstances, the measurements of progress towards optimal objectives cannot be wholly demonstrated in a quantitative form or are not feasible in specific situations, consequently, a large number of techniques with the same functions of elimination methods are developed [15], offering the ability to rank the alternative solutions, in order of preference, without using quantitative weights. The advantage of the elimination method in resource conflict resolution is that it provides an applicable approach for the elimination of infeasible solutions that do not meet specified acceptance threshold values (numeric and nonnumeric) set by the involved decision makers. By using the elimination method, the solutions (e.g. 9600 alternatives) can be greatly reduced (i.e. to 15 alternatives). The detailed method will be shown clearly in our further paper.

115.5.3 Intuitionistic Fuzzy TOPSIS Method

This stage attempts to evaluate and select the most satisfactory alternative. Many scholars have applied the intuitionistic fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method for solution evaluation and selection [16]. This paper adopts the multi-attribute decision making model using intuitionistic fuzzy method in [17] to evaluate and select the most satisfactory, or the best alternative solution of the CTF layout. The procedures for selecting the ultimate alternative is summarized as follows:

(1) Calculate intuitionistic fuzzy-set decision-making matrix.
(2) Calculate weights for the predetermined three attributes.
(3) Obtain the weighted intuitionistic fuzzy-set decision-making matrix.
(4) Identify the positive-ideal and the negative-ideal intuitionistic fuzzy solutions for the specific problem.
(5) Calculate all distances from each CTF layout alternative to the positive-ideal and the negative-ideal intuitionistic fuzzy solutions.
(6) Obtain the closeness coefficient for each alternative.
(7) Rank the preference order.
(8) Select the most satisfactory CTF layout.

The proposed CTF layout framework can be effectively used by a moderator group who solicits inputs about the conflict characteristics and stakeholders' preferences through practical interviews and meetings with the stakeholders individually or together. Such an impartial moderator group is quite important in practical construction project, who can then use the framework to suggest a balanced solution that is possible for all stakeholders to accept. By using the framework, the alternative 1 in this paper is selected as the most satisfactory one after considering the resource conflicts between the CTF layout and other 5 pre-planning tasks.

115.6 Conclusions and Future Work

Large-scale dam construction projects are often conducted in open mountainous valleys, with different general contractors and subcontractors preplanning different tasks (e.g. schedule development, workforce plan, material plan). In practical applications, resource conflicts are widely observed among these involved stakeholders. Identifying resource conflicts for the CTF layout with other pre-planning tasks is crucial for the ultimatum feasible CTF layout. Under these circumstances, this paper aims to identify and categorize potential conflicts between the CTF layout and other 5 pre-planning tasks. Based on identified conflicts, a CTF layout framework is proposed to select the CTF layout alternative which presents the least conflicts with other pre-planning tasks. However, it is noted that this paper only contains the very beginning of our current research, so the framework will be elaborated in future works.

Acknowledgments This research was supported by the Key Program of National Natural Science Foundation of China (Grant No. 70831005), the Research Foundation of Ministry of Education for the Doctoral Program of Higher Education of China (Grant No. 20130181110063), and the Program of China Scholarship Council (No. 201506240179).

References

1. Chen TY, Tsao CY (2008) The interval-valued fuzzy topsis method and experimental analysis. Fuzzy Sets Syst 159(11):1410–1428
2. Cheng M, O'Connor J (1996) Arcsite: enhanced GIS for construction site layout. J Constr Eng Manag 122(4):329–336
3. Clough RH, Sears GA, Sears SK (2000) Construction project management. Wiley, New York
4. Deutsch M (1977) The resolution of conflict: constructive and destructive processes. Yale University Press, New Haven
5. El-Rayes K, Khalafallah A (2005) Trade-off between safety and cost in planning construction site layouts. J Constr Eng Manag 131(11):1186–1195
6. Jaffar N, Tharim AA, Shuib M (2011) Factors of conflict in construction industry: a literature review. Procedia Eng 20:193–202
7. MacCrimmon KR (1973) An overview of multiple objective decision making. Multiple criteria decision making 3
8. Mok KY, Shen GQ, Yang J (2015) Stakeholder management studies in MEGA construction projects: a review and future directions. Int J Proj Manag 33(2):446–457
9. Ning X, Lam KC, Lam MCK (2010) Dynamic construction site layout planning using max-min ant system. Autom Constr 19(1):55–65
10. Osman HM, Georgy ME, Ibrahim ME (2003) A hybrid cad-based construction site layout planning system using genetic algorithms. Autom Constr 12(6):749–764
11. Osman M, Abo-Sinna MA et al (2004) A multi-level non-linear multi-objective decision-making under fuzziness. Appl Math Comput 153(1):239–252
12. Pena-Mora F, Sosa CE, McCone DS (2003) Introduction to construction dispute resolution. Prentice Hall, New Jersey
13. Pournader M, Tabassi AA, Baloh P (2015) A three-step design science approach to develop a novel human resource-planning framework in projects: the cases of construction projects in USA, Europe, and Iran. Int J Proj Manag 33(2):419–434
14. Shafaat A, Mahfouz T et al (2014) Decision making model by specialty subcontractors in construction project. In: Construction research congress 2014s construction in a global Network, ASCE, pp 867–876
15. Stein SG (2015) Contractor's and Construction Manager's Rights and Duties, vol 2. Construction Law
16. Xu J, Song X (2015) Multi-objective dynamic layout problem for temporary construction facilities with unequal-area departments under fuzzy random environment. Know-Based Syst 81:30–45
17. Ze-Shui X (2007) Methods for aggregating interval-valued intuitionistic fuzzy information and their application to decision making. Control Decis 2:019

Chapter 116
Study on Impact Factor of Quality of Life Among Adult After the Lushan Earthquake

Lili He and Yanhua Liu

Abstract QOL is one of the indicators to reveal the physical and mental health status, therefore, exploring relationship between QOL and other variables is very significant to improve post-disaster physiological and psychological rescue and survivors' QOL. The present study investigated the relationship between coping strategies (CS), posttraumatic stress disorder (PTSD), and quality of life (QOL) in the survivors suffering Lushan earthquake ($N = 1601$). The correlation analysis displayed that the QOL was significantly correlated with PTSD, CS and its six domains at the same time point (correlations were ranging from -0.42 to 0.22). Intervention strategies aimed at modifying coping strategies and decreasing PTSD symptoms could be important in improving the quality of life in the survivors experiencing many earthquakes.

Keywords Coping strategies · Post-traumatic stress disorder · Quality of life · Lushan earthquake

116.1 Introduction

Since twenty century, devastating earthquakes struck some of the global areas from time to time, such as Wenchuan earthquake in 2008, which caused enduring physical and mental problems for survivors. In turn, these problems can adversely affect quality of life. HRQOL has been defined as an "individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns" [32]. Over the past few decades, quality of life has gained recognition as an important component of health [7, 10, 15]. QOL is one of the indicators to reveal the physical and mental health status, therefore, exploring impact factor of quality of life is very significant to improve post-disaster physiological and psychological rescue and survivors' QOL.

L. He (✉) · Y. Liu
Management School, Northwest University for Nationalities, Lanzhou 730030, People's Republic of China
e-mail: 1067543705@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_116

Many studies have indicated that earthquakes can impair the quality of life (QOL) of survivors [4, 7, 10, 15, 25, 28, 35, 38]. Several follow-up studies revealed that PTSD decreased health-related quality of life [20, 24]. Research further revealed that PTSD may be associated with reduced physical and psychosocial functioning [1, 14, 16]. Therefore, PTSD could be reasonably used as impact factor of survivors' quality of life. Coping is defined as a cognitive behavioral process that continually changes to manage external or internal stressors that are apprised as exceeding individuals' resources [12]. Some study indicated that coping is related to HRQOL [3, 18, 19]. Since the role of coping strategies, as conscious efforts to manage or reduce the stressful experiences and improving the quality of life, has been shown to be a vital factor psychological reconstruction, which is worthy of further notice.

116.2 Methods

116.2.1 Procedure

In survey, a stratified sample was adopted, which ensure that the survey was systematic and scientific. Questionnaires were sent directly to the participant's home addresses or were sent out by personal interview. The questionnaires were self-completed by the participants themselves or completed by the guidance of volunteers. All participants were assured of their confidentiality and all took part voluntarily.

116.2.2 Sample

The present study, consisted of all the participants ($N = 2001$) who were mainly drawn from workers from different occupations, such as engineering, medicine, teaching, and agriculture in Lushan disaster area. Of these, 1685 had participated in the study. We asked the relevant government departments for help, which ensured a high response rate.

The study was designed in accordance with the tenets of the Declaration of Helsinki and was approved by the ethics committee of Sichuan University.

116.2.3 Instruments

(1) QQL

Sine quality of life is defined as physical, mental and social well-being [21], it has been assessed by various ways [6, 8, 13, 17, 22, 32]. Our previous study validated the standard Chinese SF-12v2 to measure QOL after earthquake [38], which is a 12-item questionnaire that assesses two dimensions, the physical component score (PCS) and the mental component score (MCS) [29, 30, 38]. Each question was measured on a 5-point Likert scale (rated 1 = not at all, 2 = slightly, 3 = moderately, 4 = severely, 5 = extremely). There were 12 questions in the questionnaire according to the 12 items. Individual item scores were accrued to arrive at a total score for each of the two dimensions and the instrument as a whole. The coefficient of Cronbach's alphas for QOL was 0.876.

(2) Coping Strategies

In our previous and present study, the coping strategies were evaluated using the Coping Scale (CS) developed by Xiao and Xu [33]. The CS consists of six domains; problem solving, self-blame, asking for help, having fantasies, problem avoidance and rationalization. There are 36 items, and each item is answered using a 5-point Likert scale where 1 = not sure at all and 5 = very sure. The questionnaire has good reliability and validity. In this study, the CS grand score was produced using a Cronbach's alpha of 0.902 in a reliability test [34].

(3) PTSD

In our previous study, the PTSD Check List-Civilian Version (PCL-C) was assessed PTSD [36, 38]. In the present study, we adopted a version of the PCL-C based on the Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV, 1994; compiled by the American Research Center for Post-Traumatic Stress Disorder). The PCL-C has been found to have good internal consistency in veteran samples, with Cronbach's alpha values > 0.94 [2, 31]. On this scale, scores for each question range from 1 (not at all) to 5 (extremely). A total symptom severity score (range $= 17 - 85$) can be obtained by summing the scores for each of the 17 items. The coefficient of Cronbach's alphas for PTSD was 0.867.

116.2.4 Data Analysis

Descriptive statistics and correlation analysis were calculated using SPSS 16.0 (SPSS, Chicago, IL, USA). T-test and bootstrapping analysis were adopted. Missing values were estimated using full information maximum likelihood (ML) procedures with all available item data [23]. All tests were 2-tailed, and significance was set at 0.05.

116.3 Results

116.3.1 Survey Responses

Table 116.1 shows frequency of demographic variables and the QOL scores for the total sample at after Lushan earthquake. For the total sample, there was an obvious

Table 116.1 The result of descriptive statistical analysis for the study sample

	N	%	QQL	
			Mean	SD
Gender			37.49	5.62
Male	792	49.5	37.5	5.61
Female	809	50.5	37.48	5.65
Age groups			37.49	5.62
18–24	54	3.4	37.97	5.75
25–34	405	25.3	38.21	5.26
35–44	549	34.3	37.97	5.51
45–54	491	30.7	36.84	5.73
55–68	102	6.3	35.52	5.65
Ethnicity group			37.49	5.62
Han	1314	82.1	37.4	5.53
Tibetan	141	8.8	38.28	5.97
Qiang	111	6.9	37.9	6.1
Hui	24	1.5	39.45	6.32
Other	11	0.7	38.65	5.13
Education level			37.49	5.62
High school or below	895	55.9	36.8	6.5
College graduate	659	41.2	37.83	5.29
Post-graduate	47	2.9	38.01	5.64
Income (RMB/month)			37.49	5.62
<1000	285	17.8	36.78	5.7
1000–2000	910	56.8	38.03	5.75
>2000	406	25.4	38.07	4.95

Note QOL = quality of life; SD = standard deviation

increase in QOL scores. The gender group only had different evaluations in QOL status. Male reported higher scores. Except for the QOL status, subjects of different ethnic groups reported different scores. The Hui ethnic group had the highest score. For income and education, two investigations revealed that higher income and education had been reported higher QOL scores.

116.3.2 Correlation Analysis

Table 116.2 presents the correlation coefficients of QOL with PTSD, CS and its six domains after Lushan earthquake. The QOL was significantly correlated with PTSD, CS and its six domains at the same time point (correlations were ranging from −0.42 to 0.22).

Table 116.2 Means, standard deviations and correlation coefficients between QOL and other variables after Lushan earthquake

	Mean	SD	QOL
QOL	37.5	5.62	1
PTSD	45.01	11.23	−0.42**
COPY	13.63	1.89	0.35*
SP	2.31	0.36	0.22*
FA	2.25	0.43	−0.16*
SB	2.16	0.42	−0.16*
AH	2.46	0.24	0.21**
RA	2.23	0.41	0.16*
AP	2.21	0.4	−0.25*

Note Bivariate correlation around 0.10 is low relativity; 0.30 is middle relativity; 0.50 is high relativity; PTSD = post-traumatic stress disorder; QOL = quality of life; PA = problem avoidance; HF = having fantasies; SB = self-blame; AH = asking for help; RA = rationalization; PS = problem solving; CS = coping strategies * $P < 0.05$; ** $P < 0.01$

116.4 Discussion

The present study revealed that PTSD and CS had a long-lasting effect on QOL among earthquake survivors. It indicated that PTSD was strongly and negatively related to the QOL, and CS was strongly and positively related to the QOL, while CS buffered the negative effect of the PTSD symptoms on the QOL among survivors after the Wenchuan earthquake.

The above result of data analysis shows that severe PTSD was related to poorer QOL, which was were consistent with previous study [9, 11, 26, 37]. At the same time, a consistent conclusion, that PTSD had an independent association with poorer QOL at multiple time points [5], was obtained in the present study by fixed effect analysis. Overall, PTSD would reduce life satisfaction, and then impair QOL after earthquake.

The present study certified that CS had obvious positive relation on QOL, and variables coping strategies was the best predict for the dependent variable quality of life. These associations are consistent with other reported findings [26]. Problem solving, asking help and rationalization were positive correlation with QOL, while self-blame, having fantasies and problem avoidance was negatively related to QOL. The result was consistent with other finding [27]. All result display that certain coping strategies have weakened physical and psychosocial functioning.

All result display that certain coping strategies have weakened physical and psychosocial functioning.

Careful psychosocial assessment can provide a basis for determining the patient's needs and how to address those needs in light of the patient's strengths and weaknesses. For many patients, adequately treating their PTSD symptoms may be sufficient to resolve their functional problems. In patients for whom functional difficulties are especially prominent, additional intervention focused on these problems should be considered jointly with, or after an adequate course of, treatment for PTSD.

Acknowledgments This research was supported by 2015 Social Science Project Planning of Lanzhou (Grant No.15-065E). We appreciated this support both in finance and in spirit. Further, we would like to thank all of the interviewees who showed great patience in answering the questionnaires.

References

1. Asmundson GJ, Stapleton JA, Taylor S (2004) Are avoidance and numbing distinct PTSD symptom clusters? J Trauma Stress 17(6):467–475
2. Blanchard EB, Jones-Alexander J et al (1996) Psychometric properties of the PTSD Checklist (PCL). Behav Res Therapy 34(8):669–673
3. Carels RA, Musher-Eizenman D et al (2004) Psychosocial functioning and physical symptoms in heart failure patients: a within-individual approach. J Psychosom Res 56(1):95–101
4. Ceyhan E, Ceyhan AA (2007) Earthquake survivors' quality of life and academic achievement six years after the earthquakes in Marmara. Turkey. Disasters 31(4):516–529
5. Chopra MP, Zhang H et al (2014) PTSD is a chronic, fluctuating disorder affecting the mental quality of life in older adults. Am J Geriatr Psychiatry 22(1):86–97
6. Clark A, Fallowfield L (1986) Quality of life measurements in patients with malignant disease: a review. J R Soc Med 79(3):165
7. Dardas LA, Ahmad MM (2015) For fathers raising children with autism, do coping strategies mediate or moderate the relationship between parenting stress and quality of life? Res Dev Disabil 36:620–629
8. First MB (1994) Diagnostic and statistical manual of mental disorders. DSM IV-4th Edition APA p 1994
9. Gentry E (2008) Posttraumatic stress disorder and health functioning in a non-treatment-seeking sample of iraq war veterans: a prospective analysis. J Rehabil Res Dev 45(3):347
10. Gladis MM, Gosch EA et al (1999) Quality of life: expanding the scope of clinical significance. J Consult Clin Psychol 67(3):320
11. Golden-Kreutz DM, Thornton LM et al (2005) Traumatic stress, perceived global stress, and life events: prospectively predicting quality of life in breast cancer patients. Health Psychol 24(3):288
12. Graven LJ, Grant JS (2013) Coping and health-related quality of life in individuals with heart failure: an integrative review. Heart Lung J Acute Crit Care 42(3):183–194
13. Group TW (1998) The World Health Organization quality of life assessment (WHOQOL): development and general psychometric properties. Soc Sci Med 46(12):1569–1585
14. Harder LH, Chen S et al (2011) The influence of posttraumatic stress disorder numbing and hyperarousal symptom clusters in the prediction of physical health status in veterans with chronic tobacco dependence and posttraumatic stress disorder. J Nerv Mental Dis 199(12): 940–945
15. Helvik AS, Bjørkløf GH et al (2016) Are coping strategies and locus of control orientation associated with health-related quality of life in older adults with and without depression? Arch Gerontol Geriatr 64:130–137
16. Kassam-Adams N, Marsac ML, Cirilli C (2010) Posttraumatic stress disorder symptom structure in injured children: functional impairment and depression symptoms in a confirmatory factor analysis. J Am Acad Child Adolesc Psychiatry 49(6):616–625
17. Katschnig H (1997) How useful is the concept of quality of life in psychiatry? Curr Opin Psychiatry 10(5):337–345

18. Kristofferzon ML, Lindqvist R, Nilsson A (2011) Relationships between coping, coping resources and quality of life in patients with chronic illness: a pilot study. Scandinavian J Caring Sci 25(3):476–483
19. Myaskovsky L, Dew M et al (2003) Avoidant coping with health problems is related to poorer quality of life among lung transplant candidates. Progr Transp 13(3):183–192
20. Olatunji BO, Cisler JM, Tolin DF (2007) Quality of life in the anxiety disorders: a meta-analytic review. Clin Psychol Rev 27(5):572–581
21. Organization WH (1948) Constitution of the world health organization. The Organization
22. Sartorius N, Kuyken W (1994) Translation of health status instruments. In: Quality of life assessment: International perspectives. Springer, Heidelberg, pp 3–18
23. Schafer JL, Graham JW (2002) Missing data: our view of the state of the art. Psychol Methods 7(2):147
24. Schnurr PP, Lunney CA et al (2009) Posttraumatic stress disorder and quality of life: extension of findings to veterans of the wars in Iraq and Afghanistan. Clin Psychol Rev 29(8):727–735
25. Seplaki CL, Goldman N et al (2006) Before and after the 1999 Chi-Chi earthquake: traumatic events and depressive symptoms in an older population. Soc Sci Med 62(12):3121–3132
26. Solomon Z, Mikulincer M (2007) Posttraumatic intrusion, avoidance, and social functioning: a 20-year longitudinal study. J Consult Clin Psychol 75(2):316
27. Taylor S, Wald J, Asmundson GJ (2007) Factors associated with occupational impairment in people seeking treatment for posttraumatic stress disorder. Canadian J Commun Mental Health 25(2):289–301
28. Wang L, Cao C et al (2012) The dimensionality of PTSD symptoms and their relationship to health-related quality of life in Chinese earthquake survivors. J Anxiety Disord 26(7):711–718
29. Ware JE, Kosinski M et al (2002) How to score version 2 of the SF-12 health survey (with a supplement documenting version 1). Quality Metric Incorporated
30. Ware JE Jr, Kosinski M, Keller SD (1996) A 12-item short-form health survey: construction of scales and preliminary tests of reliability and validity. Med Care 34(3):220–233
31. Weathers FW, Litz BT et al (1993) The PTSD Checklist (PCL): Reliability, validity, and diagnostic utility. In: Annual convention of the international society for traumatic stress studies, International society for traumatic stress studies San Antonio
32. WHO (1995) The World Health Organization quality of life assessment (WHOQOL): position paper from the World Health Organization. Soc Sci Med 41(10):1403–1409
33. Xiao J, Xu X (1996) The study on reliability and validity of 'The Coping Scale'. Chinese Mental Health J 10(4):164–166
34. Xu J, He Y (2012) Psychological health and coping strategy among survivors in the year following the 2008 Wenchuan earthquake. Psychiatry Clin Neurosci 66(3):210–219
35. Xu J, Ou L (2014) Resilience and quality of life among wenchuan earthquake survivors: the mediating role of social support. Pub Health 128(5):430–437
36. Xu J, Song X (2011) Posttraumatic stress disorder among survivors of the wenchuan earthquake 1 year after: prevalence and risk factors. Compr Psychiatry 52(4):431–437
37. Zatzick DF, Marmar CR et al (1997) Posttraumatic stress disorder and functioning and quality of life outcomes in a nationally representative sample of male vietnam veterans. Am J Psychiatry
38. Zhao C, Wu Z, Xu J (2013) The association between post-traumatic stress disorder symptoms and the quality of life among wenchuan earthquake survivors: the role of social support as a moderator. Qual Life Res 22(4):733–743

Chapter 117
Power Plants Planning Modelling-Based Carbon Emission Allowance Allocation Problem with Changing Supply-Demand Relationship

Ye Wang, Tao Zhang, Yijun Zhou and Chengwei Lv

Abstract This paper discusses a carbon emission allowance allocation problem from a regional authority's perspective under a fuzzy environment, which is a multi-objective optimization process. Uncertain parameters are depicted as fuzzy variables and fuzzy expected value notions are introduced to cope with the uncertainty. A fuzzy logic controlled genetic algorithm is designed as a solution method to solve the above problem. Finally, the results of a case study for the carbon emission allowance allocation problem about China Southern Power Grid Company Limited are proposed to show the practicality and efficiency of the optimization method.

Keywords Carbon emission allowance allocation · Multi-objective optimization · FLC-GA · Fuzzy environment

117.1 Introduction

Climate changes have been paid more and more attention of human beings [7, 12]. The Fifth Assessment of the Intergovernmental Panel on Climate Change (IPCC) has shown through multiple lines that the climate is changing across our planet [5]. Generally, a majority of carbons discharged into the atmosphere are from combustion of fossil fuels such as coal, oil and natural gas. Its emission is closely related to all aspects of our life, such as power generation, transportation, as well as industrial, residential and commercial activities. Specially, fossil fuel burning in the electric power system is one of the major contributory factors for the increase of carbon from human activities over the last 20 years, which accounts for about three-quarters. Since it is undeniable to depend on fossil fuels combustion for energy generation and

Y. Wang · T. Zhang
Economic Management Institute, Guiyang University,
Guiyang 550005, People's Republic of China

Y. Zhou (✉) · C. Lv
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: yijundaisy@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_117

supply, carbon emission will increase obviously and lead to more serious problems involving economy, environment and health.

Due to the harmful impact of excessive carbon emission brings, Kyoto Protocol, which was signed in 1997, is to respond to climate changes through reducing carbon emission. The Emission Trading Scheme, a market-based approach by providing carbon allowances as economic incentives, was put forward for the first time in this protocol [2, 8, 11]. As of January 2005, CET is successfully implemented in the European Union. One of the most controversial issues in the ETS is how the allowances will be distributed. Since the ETS creates a great value for carbon reduction, decisions about the allocation result in an issue of very high significance world-wide. It involves whether to choose free allocation or auction or a combination of both [6, 9]. Emerging programs have changed in the transition from free allocation to auction over time, but free allocation will surely continue to play a important role at least up to 2020 [4]. Research on free carbon emission allowances allocation problem (CEAAP) has attracted plenty of attentions in the last few decades.

As big emitters, the electric power systems must be taken into consideration to mitigate carbon emissions. This issue has drawn a lot of researchers' attention. For example, Chappin proposed an agent-based model to elucidate the influences of CET on the investments in Dutch electricity generation [1]. Later, Cong and Wei studied the potential impact of introduction of CET on China's power sector and discussed the impact of different allocation options of allowances [3]. Recently, Zhu et al. managed carbon emissions of Beijing' electric power system under CET mechanism [15]. All of them put a point of view on the macro planning of whole electric power-suppy industry in long term. The power plant for electricity generation, as one of the most important related to the electric power system, has became main target where carbon emission mitigation is important because of highly centralized carbon emissions [10]. As an energy generation enterprise, the plant is responsible for electricity generation and the production amount varies with the different allowances. For the leader of CEAAP, regional authority must consider the electricity supply of power plants to meet the social demand firstly, beside the satisfaction and efficiency of the allocation. Therefore, CEAAP from regional authority's perspective needs to be researched. To our knowledge, there have been few scholars whose studies have involved the problem. To study it, a multi-objective model is formulated.

The need to address uncertainty in carbon emission allowance allocation problem is widely awaked, as uncertainties exist in all kinds of system components. For example, the demand for electricity is not fixed because of the influences of many uncertain elements. In the global power-supply industry, where accurate statistical data are often effected by weather, temperature and location, it is proper for using fuzzy variables to model the statistical data and expert' experience. In this study, because it is very difficult to estimate the precise value of demand for electricity, with expert giving a range, i.e. (a, b, c), as shown in Fig. 117.1.

This paper is structured as follows. Following the introduction, a multi-objective programming model for the carbon emission allowance allocation problem with uncertainty and the formulation of its equivalent crisp model for solving the problem is the scope of Sect. 117.2. In Sect. 117.3, we design a fuzzy logic controlled genetic

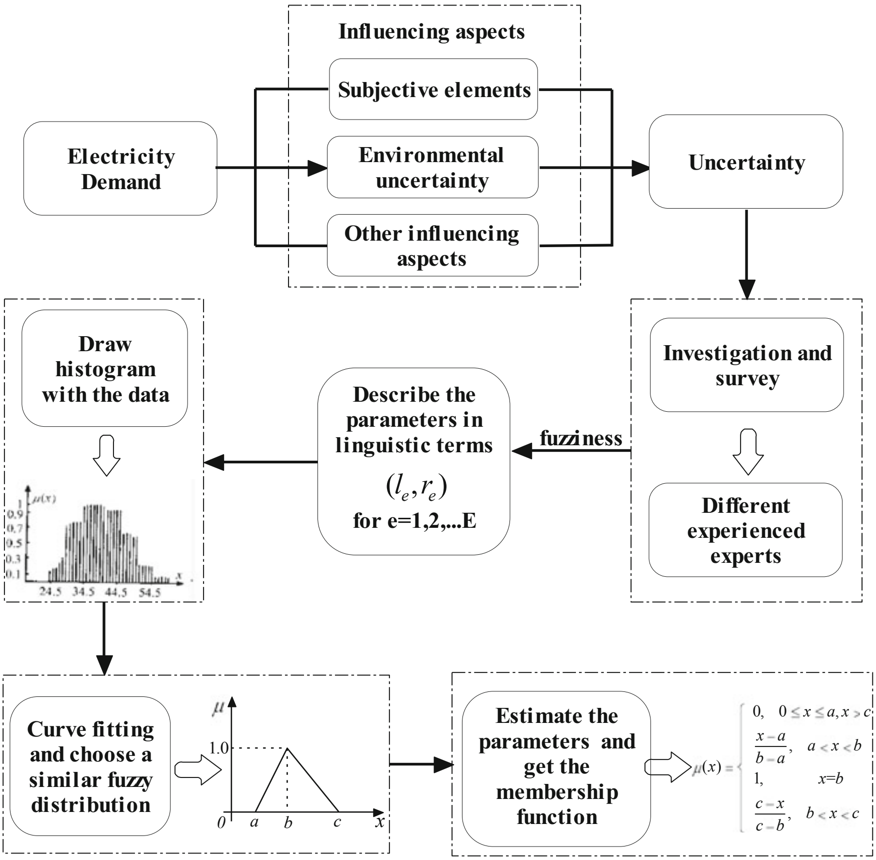


Fig. 117.1 Flow chart of uncertain approach to demand for electricity

algorithm is to solve the equivalent crisp model. The results of a case study about China Southern Power Grid Company Limited are presented to demonstrate the practicality and efficiency of the optimization method in Sect. 117.4. In the final section, the conclusions and directions for future research are presented.

117.2 Modelling

In this section, a multi-objective programming for the allocation problem with incomplete uncertainties is constructed. The mathematical description of the problem is given as follows.

117.2.1 Notations

In order to facilitate the description of the problem, the following notions are introduced.

i : index of the coal-fired power plants, $i = 1, 2, \ldots, I$;

$\widetilde{D}$: demand for electricity in this year;
$\widetilde{p}_c$: unit price of carbon allowance;

$B_i^{\min}$: minimum expect benefit of plant i;

$B_i^{\max}$: maximum expect benefit of plant i;
p_e: unit price of electricity;

c_i: the current carbon needed for per unit electricity of plant i;

g_i: the amount of electricity generation of power plant i;
s_i: the satisfaction level of power plant i;

m_i: the carbon emission allowances allocated to power plant i.

117.2.2 CEAAP Model with Fuzzy Parameters

For the regional authority, the key issue is how to allocate the carbon emission allowances. A multi-objective model is proposed in this paper for carbon emission allocation policy of the regional authority. What we take into account are the emission reduction target and electricity supply, besides the satisfaction and efficiency of the allocation. The mathematical description in detail is shown as follows.

(1) Reduction Target

One of the efficiencies of the allocation is to come up with the emission reduction goal. The regional authority expects to limit the total carbon emission with a cap through allocating allowances to everyone. However, under the cap and trade mechanism, the actual emission from every plant may exceed the allowance it got. A goal of an absolute cap is undesirable and impossible to achieve. A relative emission reduction target to make the actual total emission as little as possible may be feasible, i.e.

$$\min\ M = \sum_i m_i. \tag{117.1}$$

(2) Satisfaction level

As shown in notations, $B_i^{\min}$ and $B_i^{\max}$ are the minimum and maximum of the expect benefit for plant i, respectively. When the regional authority begins to control the carbon emission and allocate free allowance, each plant will change its production plan to take advantage of the allowance most effectively. The electricity supply will change, spontaneously. As a kind of energy resource relating to human life, satisfaction level for plants is defined by the function:

$$\widetilde{s_i}(m_i) = \begin{cases} 0, & g_i \times p_e - \widetilde{p_c} \times (g_i \times c_i - m_i) \le B_i^{\min}; \\ \frac{g_i \times p_e - \widetilde{p_c} \times (g_i \times c_i - m_i) - B_i^{\min}}{B_i^{\max} - B_i^{\min}}, & B_i^{\min} < \sum_i s_i \le B_i^{\max}; \\ 1, & g_i \times p_e - \widetilde{p_c} \times (g_i \times c_i - m_i) \ge B_i^{\max}. \end{cases} \tag{117.2}$$

The satisfaction level function assumes that if the benefit is less than the minimum expect benefit $B_i^{\min}$, the satisfaction level is reduced to zero. The satisfactory level grows with the increase of benefit. However, if the benefit increases to be more than the maximal expect benefit $B_i^{\max}$, the satisfaction level of that subarea cannot increase to more than one. As a result, the objective function for the satisfaction level is to maximize the minimal satisfaction level of plants:

$$\max S = \min \ \widetilde{s_i}(m_i). \tag{117.3}$$

(3) Demand Constraints

To ensure allocations sustainability, the allowances allocated to each plant cannot be less than the demand for electricity in this year:

$$\sum_i m_i \ge \widetilde{D}. \tag{117.4}$$

(4) Benefit Constraints

In addition, the airfare revenue cannot be less than the cost:

$$g_i \times p_e \ge \widetilde{p_c} \times (g_i \times c_i - m_i), i = 1, 2, \ldots, I. \tag{117.5}$$

(5) Allowance Constraints

Besides, the carbon emission allowances allocated cannot be negative:

$$m_i \ge 0, i = 1, 2, \ldots, I. \tag{117.6}$$

117.2.3 Global Model

To control the emission of carbon, the regional authority has to allocate the carbon emission allowances to the enterprises participated in emission reduction action. As one of the major emitters, the coal-fired power plants are included with no doubt. In this paper, the regional authority takes the "cap-trade" mechanism and allocates the allowances freely to the plants first. When allocating, the regional authority should consider the efficiency of the allocation. Besides, since electricity is an indispensable resource is daily life, the regional authority also seeks to maximize the social satisfaction degree for the electricity supplies so as to meet the daily electricity demand. If the emissions from the generation are less than the allowances allocated, the leftover could be sold to obtain economic benefits. Oppositely, if the allowances are not enough, the trade-off between purchasing allowances and investing in emission reduction is necessary for the plant. Based on the analysis above, the following global model for the multi-objective optimization model with fuzzy variables can be formulated as:

$$\begin{cases} \min \sum_i m_i \\ \max \min \ \tilde{s}_i(m_i) \\ s.t. \begin{cases} \sum_i m_i \geq \tilde{D}, \\ g_i \times p_e \geq \tilde{p}_c \times (g_i \times c_i - m_i), i = 1, 2, \ldots, I, \\ m_i \geq 0, i = 1, 2, \ldots, I. \end{cases} \end{cases}$$

117.2.4 Techniques for Handling Fuzzy Parameters

As discussed above, a multi-objective model with fuzzy parameters is constructed. Since uncertain quantities cannot be minimized or maximized, the fuzzy parameter is also unable to be maximized or minimized. Therefore, certain techniques need to be employed. In this paper, the expected value is employed to deal with the objective functions and constraints.

The expected value is widely adopted in many areas to measure the mean. In the fuzzy programming, it can also be used. Here, the expected value is employed to deal with the objective function. There are many relevant definitions about the expected value in fuzzy theory, such as Pos, Nec and Cr. The measure Pos means an absolutely optimistic attitude while Nec means an absolutely pessimistic attitude. The measure Cr means a composite attitude which as a combination of half optimistic and half pessimistic. In a realistic decision problem, the attitudes of the different decision makers are different. Thus, the expected value based on Me is adopted. Then the multi-objective model is transformed as:

$$\begin{cases} \min \sum_i m_i \\ \max \min \ \frac{(1-\lambda)s_i(m_i)^{k1}+s_i(m_i)^{k2}+\lambda s_i(m_i)^{k3}}{3} \\ s.t. \begin{cases} \sum_i m_i \geq \frac{(1-\lambda)D^{k1}+D^{k2}+\lambda D^{k3}}{3}, \\ g_i \times p_e \geq \frac{(1-\lambda){p_c}^{k1}+{p_c}^{k2}+\lambda {p_c}^{k3}}{3} \times (g_i \times c_i - m_i), i = 1, 2, \cdots, I, \\ m_i \geq 0, i = 1, 2, \cdots, I. \end{cases} \end{cases}$$

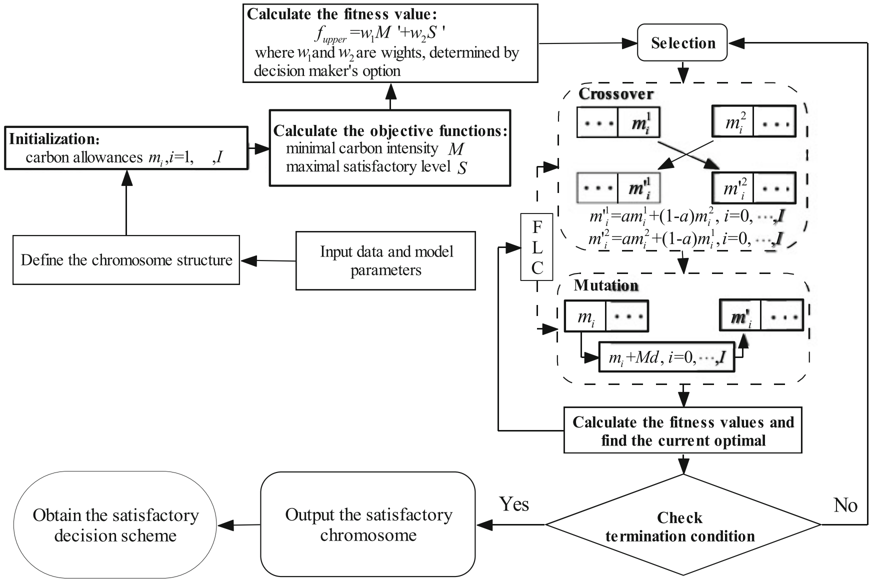


Fig. 117.2 Flow chart of the FLC-GA

117.3 Procedure Based on FLC-GA

The proposed model offers the low-carbon power-supply industry with an effective tool to treat with the carbon emission allowance allocation optimization. However, the inherently complex environment, with a changing climate, and fluctuant power-supply demand, usually needs the proposed model to dynamically satisfy various scenarios. Therefore, a procedure for regional authority formulation based on FLC-GA is planned to simulate the carbon emission allowance allocation optimization and further accelerates the plants to evolve effective strategies.

In the method of this paper, the fuzzy logic controllers are introduced to escape from the local optimum and adaptively adjust the rates of crossover and mutation operators [14]. Besides, since the objectives of this approach is to minimize the total carbon emission allowances and maximize the minimal satisfaction level of plants while the precedence constrained are satisfied, a weighted-sum procedure is adopted to deal with the multiple objectives [13]. The framework for the overall FLC-GA is shown in Fig. 117.2.

117.4 Practical Application

In this section, the carbon reduction planning of China Southern Power Grid Company Limited is used as a practical application example for the proposed optimization method. With rapid economic development, China's energy consumption, especially

Table 117.1 Detailed data about basic information of every power plant

The power plant index i	Items			
	Carbon needed c_i (ton/ KWh)	Electricity generation g_i (10^8 KWh)	Maximum benefit $B_i^{\max}$ (10^8 CNY)	Minimum benefit $B_i^{\min}$ (10^8 CNY)
$i = 1$	0.82	1092.34	112.81	100.77
$i = 2$	0.78	1185.11	120.53	103.23
$i = 3$	0.75	1123.79	121.01	102.98
Unit price of electricity p_e (CNY)		Unit price of carbon allowance $\widetilde{p}_c$ (CNY)		Demand for electricity in this year $\widetilde{D}$ (10^4 ton)
1.17		(5.8, 6.3, 6.9)		(667.71, 683.03, 689.29)

electricity consumption, has increased rapidly. According to the statistics, coal-fired power occupies more than 75 % of China's total electricity generation, which means large amounts of carbon have discharged into atmosphere. Up to now, China has been the second largest greenhouse gas emitter throughout the world, with enormous pressures in the international negotiation on carbon emissions control and climate change mitigation. At the Copenhagen climate conference in 2009, China government pledged that China would cut down carbon emission intensity (i.e. carbon emissions per unit GDP) by 40–45 % based on 2005 level by 2020. As part of China's national plan, this intensity has also been proposed in China's 13th Five-Year Plan. To achieve this target, China still employs CET mechanism adopted by many other countries. The corresponding data of which are stated in Table 117.1. It should be noticed that the fuzzy parameters in Table 117.1 are got by the following steps:

(1) investigations and surveys. For electric demand, 50 experts are requested to conduct the investigation for many periods. Each expert provides us with the ranges of the electric demand relying on their experiences;
(2) making the minimum and maximum value of all groups as the lower and upper bound of the fuzzy number;
(3) supposing that the most possible value to approximately follow normal distributions for every period, and using the maximum likelihood estimation method to estimate the two parameters (i.e., expected value and variance) for the normal distributions;
(4) using goodness-of-fit testing to justify the appropriateness of the normal distribution in modeling the observed data;
(5) finally, the fuzzy number is obtained.

In order to demonstrate the practicality and efficiency of the proposed method for the carbon emission allowance allocation problem which is presented in this paper, the fuzzy logic controlled genetic algorithm was developed and ran on MATLAB (the population size $N_{\text{pop-size}} = 70$, the probability of crossover $p_c = 0.6$ and the probability of mutation $p_m = 0.04$. After running 500 generations, the final solution is $(m_1, m_2, m_3) = (270.62, 211.21, 203.07)$. In addition, the objective function values are $(M, S) = (684.90, 0.83)$.

117.5 Conclusions and Future Research

This paper studied a carbon emission allowance allocation problem from a regional authority's perspective. For the regional authority, there are two objectives, so this model is also a multi-objective model. Since the environment of the carbon emission allowance allocation problem is fuzzy, the relevant objectives of the model are considered with fuzzy numbers. Then a CEAAP model with fuzzy numbers is proposed. To cope with fuzzy numbers, the expected value based on the fuzzy measure Me is adopted, which allows the pessimistic-optimistic parameters to be adjusted by the decision maker and thus is more appropriate for use in the real world situations. From this method, a crisp model for the CEAAP model is built. To solve the crisp model, a FLC-GA is designed. Finally, we give a case study about China Southern Power Grid Company Limited to show the feasibility of the proposed method.

In the future, our research plans to focus on different uncertain environment (e.g. rough), carbon tax setting problem and air route selection problem in multiple stages.

References

1. Chappin EJ (2006) Carbon dioxide emission trade impact on power generation portfolio. Agent-based Modelling to Elucidate Influences of Emission Trading on Investments in Dutch Electricity Generation
2. Clo S (2009) The effectiveness of the eu emission trading scheme. Clim Policy 9:227–241
3. Cong RG, Wei YM (2010) Potential impact of (CET) carbon emissions trading on China's power sector: a perspective from different allowance allocation options. Energy 35(9):3921–3931
4. Hong T, Koo C, Lee S (2014) Benchmarks as a tool for free allocation through comparison with similar projects: focused on multi-family housing complex. Appl Energy 114:663–675
5. IPCC (2013) Summary for policy makers, concentrations of atmospheric greenhouse gases. IPCC TAR WG1
6. Lopomo G, Marx LM et al (2011) Carbon allowance auction design: an assessment of options for the United States. Rev Environ Econ Policy 5(1):25–43
7. Peters GP, Andrew RM et al (2013) The challenge to keep global warming below 2 °C. Nat Clim Chang 3(1):4–6
8. Qiu R, Song X, Zhong L (2015) Airline planning modelling-based carbon taxes setting problem under changing transportation environment. In: Proceedings of the ninth international conference on management science and engineering management. Springer, Berlin, Heidelberg pp 347–355
9. Rosendahl KE, Storrøsten HB (2015) Allocation of emission allowances: impacts on technology investments. Clim Chang Econ 6(03):1550010

10. Sims RE, Rogner HH, Gregory K (2003) Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation. Energy Policy 31(13):1315–1326
11. Svendsen G (1999) The idea of global CO_2 trade. European Environment
12. Thompson TM, Rausch S et al (2014) A systems approach to evaluating the air quality co-benefits of US carbon policies. Nat Clim Change
13. Xu J, Zheng H et al (2012) Discrete time-cost-environment trade-off problem for large-scale construction systems with multiple modes under fuzzy uncertainty and its application to Jinping-II hydroelectric project. Int J Proj Manag 30:950–966
14. Yun Y, Gen M (2003) Performance analysis of adaptive genetic algorithms with fuzzy logic and heuristics. Fuzzy Optim Decis Mak 2:161–175
15. Zhu Y, Li YP, Huang GH (2013) Planning carbon emission trading for Beijing's electric power systems under dual uncertainties. Renew Sustain Energy Rev 23:113–128

Chapter 118
Popularity Evaluation of Lean Thinking in Southwest China

Richard Adu Agyapong, Yi Lu, Shinebayar Choidorj and Troy De La Harpe

Abstract Lean Thinking is a value creation process and system which enables an organization to create value as the customers and clients defines it. It is a management philosophy as well as a methodology. Lean operates by a set of principles and is flexible enough to be supplemented by other tools and techniques. Lean Thinking emerged as a concept and strategy from the auto-manufacturing sector. Over the past two and a half decades, Lean Thinking has spread into many other sectors. It is also gradually spreading into many countries and emerging markets. The aim of this paper is to evaluate the popularity of Lean Thinking in Southwestern China.

Keywords Lean thinking · Value · Managers · Southwestern China · Empirical study

118.1 Introduction

According to Porter [13], in order to deliver value to clients and customers, organizations need to have a strategy in place. Womack and Jones [19], explained that value creation is inevitable if an organization aims to be successful. Lean Thinking is a value creation process and system which enables an organization to create value as the customers and clients defines it.

Lean Thinking is simply defined as 'creating more value for customers with fewer resources'. It is a methodology that seeks to provide a new way to organize corporate

R.A. Agyapong · Y. Lu (✉)
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: luyiscu@163.com

S. Choidorj
Zest bag, Bayan-Undur soum, Erdenet City, Orkhon Province 61000, Mongolia

T. De La Harpe
Dipidax Road, Bloubergstrand, Cape Town 7441, South Africa

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_118

activities and processes to deliver more value to customers and also satisfaction to staff while eliminating waste. Lean Thinking has been acknowledged as a methodology that improves businesses [18, 19]. Lean methodology has been applied in many areas such as manufacturing, Construction, health, supply chain, marketing, Hospitality etc. [1–3, 8, 17].

Lean Thinking is about making the most out of the limited resources an organization has by eliminating waste (non-value adding processes) in order to create value as the customer sees it [18, 20]. Lean Thinking gained grounds in the 1990s [7].

"The elimination of non-value-added activities reduces costs and cycle time, which results in agile, customer-responsive and more competitive organizations" as cited in Ciarniene and Vienazindiene [7].

Lots of research attribute the roots of Lean Thinking to the Toyota Production System because of its emphasis on waste reduction [12, 18–20].

According to scholars like Hopp and Spearman [9] and Staats et al. [11], 'Lean' was coined by Krafcik to show the idea of reducing 'waste' (excess inventory).

Over the years, Lean has evolved to become a business and production philosophy that embraces multidimensional management practices including work teams, supplier management, quality systems etc. aimed at getting rid of waste in a product/service's value stream and giving customers and clients what they want based on a continuous improvement ideology. Lean operates by a set of principles; specifying value (in the eyes of the customer), identifying the value stream, ensuring the flow of value in the value stream, enabling clients/customers to pull value, and pursuing Kaizen (perfection). An in-depth understanding and application of these principles is vital for the successful implementation of Lean [4–6, 10, 14, 15, 17–20].

Lean, which started in the manufacturing industry has spread into the service sector. Scholars such as Simon and Canacari [16] have all done works about lean in the service sector.

Despite numerous research done in the field of Lean Thinking globally, empirical research in Lean Thinking and Lean methodology in China is relatively little. This paper seeks to find out how popular lean thinking is in Southwest China.

118.2 Methodology

This paper seeks to find out how popular lean thinking is in Southwest China (see Fig. 118.1). In order to realize this target, a questionnaire (comprising both close and open ended questions) was employed to help collect data from a number of line managers and senior level managers. The general operational processes of their organizations were mapped out. To do this, the following targets were set:

- Structure the questionnaire in a way that will help capture their understanding of Lean Thinking.
- Have a short interview with the respondents, asking about the operational procedure of their organizations.

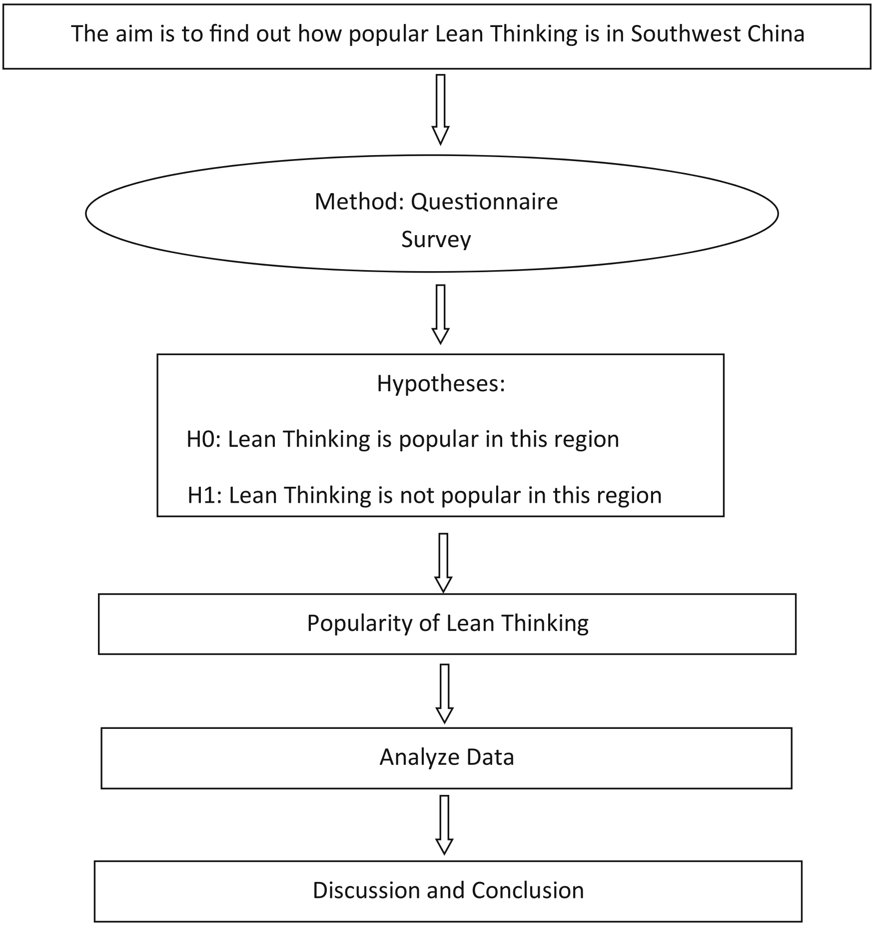


Fig. 118.1 Conceptual Framework

The research was based on the following hypothesis:

Hypothesis 0 (H0): Lean Thinking is popular in this region.

Hypothesis 1 (H1): Lean Thinking is not popular in this region.

83 out of 100 questionnaires given to managers in a total of 100 companies in different fields of operation were returned. These managers are working in the pharmaceutical, hospitality, retail, finance and education sectors.

The respondents were randomly sampled from Multinational Corporations and indigenous companies. These companies mostly operate in Sichuan Province, Chongqing, Guizhou Province and Yunnan Province from their regional headquarters located in Chengdu.

Respondents are generally mid-level and line managers with a minimum education of a bachelor's degree. Average years of working experience is 4.63 years. The respondents frequently move from branch to branch, city to city and province to province to deal with their clients and teams.

The questionnaires were sent out via a survey app (Survey Monkey).

118.3 Results and Analysis

Analysis revealed that 83 % of managerial employees in the region do not know exactly what Lean Thinking involves. 13 % of them think it raises customer satisfaction, 8 % think it is about cost reduction. A further 12 % of them are of the view that it is about continuous improvement, 4 % see it as enhancing employee satisfaction, 11 % considers it as improving quality, and 6 % are of the opinion that it minimizes waste (see Fig. 118.2).

The results of the analysis as to whether their organizations use Lean Thinking or not is presented in Fig. 118.3. 83 % of the respondents answered 'no', and 17 % answered in the affirmative. This calls for not rejecting the alternate hypothesis H1: Lean Thinking is not popular in this region (see Fig. 118.3).

From the analysis, 83 % of the respondents do not know anything about the 5 principles of Lean Thinking. 11 % know the principles vaguely, whereas 6 % have 'OK' knowledge of the Lean Thinking principles. None of the managers surveyed, know the Lean Thinking principles very well. See the results in the chart below (see Fig. 118.4).

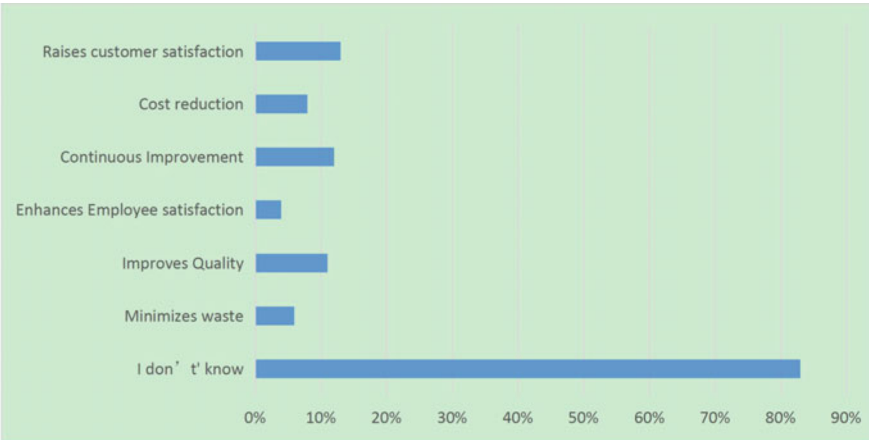


Fig. 118.2 Managers' idea of what lean thinking involves

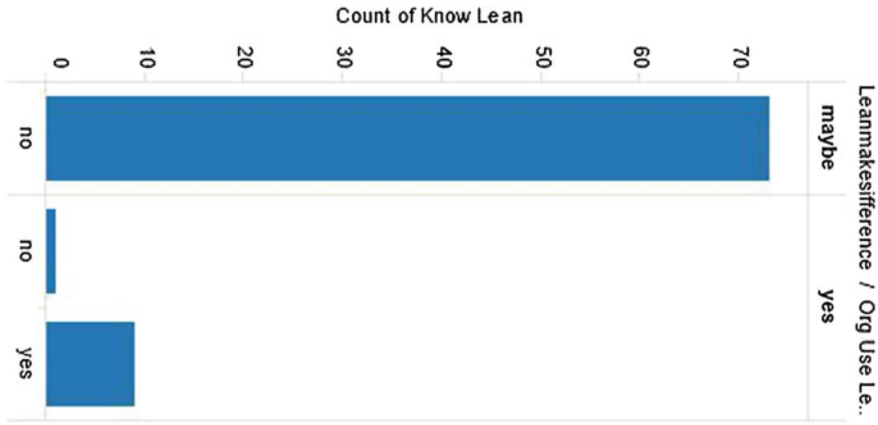


Fig. 118.3 Managers' response to whether they think lean will make a difference or not

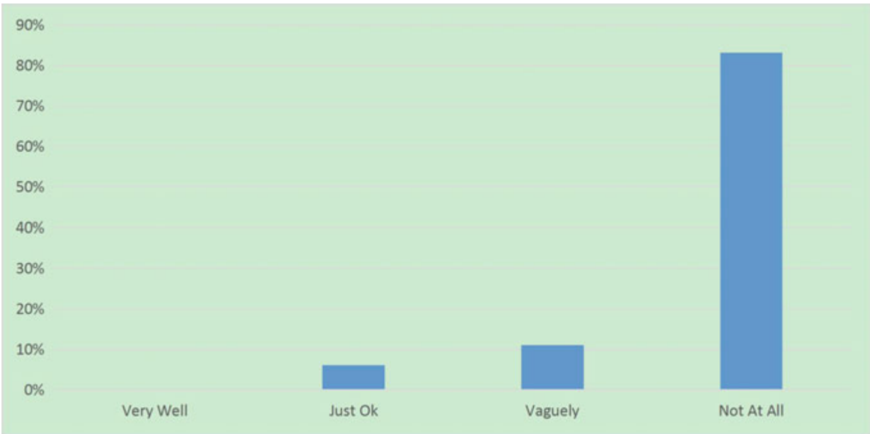


Fig. 118.4 Managers knowledge of the lean thinking principles

118.4 Conclusion

The result of this empirical research indicates that more than two-thirds of the respondents have no knowledge of Lean Thinking. This enables the rejection of H0: Lean Thinking is popular in this region. The Chinese business environment can be said to be turbulent. It is our recommendation that corporate managers make time out of their busy schedules to familiarize themselves with relatively new concepts which have proven track records like Lean Thinking. This, we believe, will further ensure the competitiveness of their teams and organizations.

Also, this research discovered that 83 % of the companies surveyed do not use Lean Thinking as a corporate philosophy or in their day to day operations. Only 17 % of the respondents claim that their organizations use Lean Thinking. This implies we do not reject the alternative hypothesis; Lean Thinking is not popular in this region. Globally, various companies have shown how successful Lean Thinking can be. Examples of such companies include Toyota and Coca-Cola among others.

Moreover, out of the 17 % of the respondents who had knowledge about Lean Thinking, only 6 % describes their knowledge of the 5 Lean Principles as 'Just OK'. 11 % said they have a vague understanding of the 5 principles of Lean Thinking. This goes a long way to call for not rejecting of the alternative hypothesis that Lean Thinking is not popular in this region. Regarding this, we recommend that professional courses in Lean Thinking ought to be mounted in this region. We believe that this will enable managers to get access and possibly take these courses.

References

1. Atkinson P (2010) Lean is a cultural issue. Manag Serv 54(2):35–41
2. Azevedo SG, Carvalho H et al (2012) Influence of green and lean upstream supply chain management practices on business sustainability. IEEE Trans Eng Manag 59(4):753
3. Azevedo SG, Govindan K et al (2012) An integrated model to assess the leanness and agility of the automotive industry. Resour, Conserv Recycl 66:85–94
4. Bhasin S, Burcher P (2006) Lean viewed as a philosophy. J Manuf Technol Manag 17(1):56–72
5. Bicheno HMJ (2009) The lean toolbox. Picsie, Buckingham
6. Bollbach M (2012) Country-specific barriers to implementing lean production systems in China. Ph.D. thesis, Marc Fabian Bollbach
7. Ciarniene R, Vienazindiene M (2015) An empirical study of lean concept manifestation. Procedia-Soc Behav Sci 207:225–233
8. Goerke M, Schmidt M et al (2015) Holistic approach of lean thinking in learning factories. Procedia CIRP 32:138–143
9. Hopp WJ, Spearman ML (2004) To pull or not to pull: what is the question? Manuf Serv Oper Manag 6(2):133–148
10. Howell G (2001) Introducing lean construction: reforming project management. Report Presented to the Construction User Round Table (CURT), Lean Construction Institute
11. Krafcik JF (1988) Triumph of the lean production system. MIT Sloan Manag Rev 30(1):41
12. Monden Y (2011) Toyota production system: an integrated approach to just-in-time. CRC Press, Boca Raton
13. Porter ME (2008) On competition. Updated and expanded ed. The Harvard business review book series. Harvard Business School Publishing, Boston
14. Shah R, Ward PT (2007) Defining and developing measures of lean production. J Oper Manag 25(4):785–805
15. Sharma SK, Gupta RD et al (2011) Supplier issues for lean implementation. Int J Eng Sci Technol 3(5):3900–3905
16. Simon RW, Canacari EG (2012) A practical guide to applying lean tools and management principles to health care improvement projects. AORN J 95(1):85–103
17. Spear SJ (2004) Learning to lead at toyota. Harv Bus Rev 82(5):78–91
18. Womack J, Jones D (1996) Lean thinking: banishing waste and creating wealth in your corporation. Simon & Schuster, New York

19. Womack J, Jones D (2003) Lean thinking: banishing waste and creating wealth in your corporation. Simon & Schuster, New York
20. Womack JP, Jones DT, Roos D (1990) Machine that changed the world. Simon & Schuster, New York

Chapter 119
An Overview of Earned Value Management in Airspace Industry

Juan Carlos Meléndez Rodriguez, Joaquín López Pascual, Pedro Cañmero Molina and Fausto Pedro Garcła Márquez

Abstract Earned value management (EVM) is an effective project management approach. This method is used to manage project of different sectors and has been revised to improve its schedule estimates, the Earned Schedule Management and the Earned Duration Management and to include new components as quality, the quality earned value management. This paper explores the EVM methodology and proposes a model to manage projects aerospace engineers based in a real case study. The inputs in the model are the planning and the monitoring of the case study, planned value, earned value and actual cost of aerospace projects.

Keywords Earned value management · Earned schedule management · Earned duration management · Quality earned value management · Planned value · Earned value and actual cost · Airspace

119.1 Earned Value Management

The Earned Value Management (EVM) is a robust and effective approach for the performance of the project management. This method integrates scope, cost and time management in a single tool. EVM needs a periodic monitoring of the project and provides early indication of rates for the project management that leads adjust project strategy to carry out the planned budget and schedule.

EVM used a cost and schedule planning as baseline and two parameters to carry out the monitoring of project: The Planned Value (PV) is the baseline, defined as the time-phased budged package; Actual Cost (AC) and Earned Value (EV), that are the monitoring parameters, being AC the actual cost spent on time and EV is the work that was accomplished [2]. The EV is given by Eq. (119.1).

J.C.M. Rodriguez · J.L. Pascual
Juan Carlos I University, Mostoles, Spain

P.C. Molina · F.P.G. Márquez (✉)
Ingenium Research Group, Castilla-La Mancha University, Ciudad Real, Spain
e-mail: FaustoPedro.Garcia@uclm.es

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_119

$$EV = \%\text{Progress} \times PV \ \text{ total.} \tag{119.1}$$

The technique of EV analysis requires evaluating variance between the parameters EV, AC and PV. The Cost Variance (CV) is utilized to identify if the project is more or less the planned value.

$$CV = EV - AC. \tag{119.2}$$

When the CV is negative, then the project is more than the budget, and if it is positive then the project is under budget. The Schedule Variance (SV) is the indicator to represent how advanced the project on schedule.

$$SV = EV - PV. \tag{119.3}$$

The SV analysis is similar to CV, a positive values means that the project is ahead to the planned schedule, and when it is negative means that a project is delayed from planned schedule. The indices Cost Performance Index (CPI) and the Schedule Performance Index (SPI) are used to evaluate the efficiency.

$$\text{CPI} = EV/AC, \tag{119.4}$$

$$\text{SPI} = EV/PC. \tag{119.5}$$

CPI and SPI indices indicate the efficiency of the project in cost and schedule. The main acronyms and definitions of EVM are given in Practice Standard for Earned Value Management of PMI (Fig. 119.1).

The approach does a projection of the Estimate at Completion (EAC) that may differ from the Budget At Completion (BAC) was developed. It allows analyzing PV with an estimate of cost (from AC) and schedule estimation (from EC) from the current time. This analysis results the following parameters and index (Fig. 119.2):

- **BAC**: Budget at completion. This is the total budget baseline of project.
- **ECD**: Estimate completion date.
- **PCD**: Planned completion date.
- **ECD**: Estimate completion date.

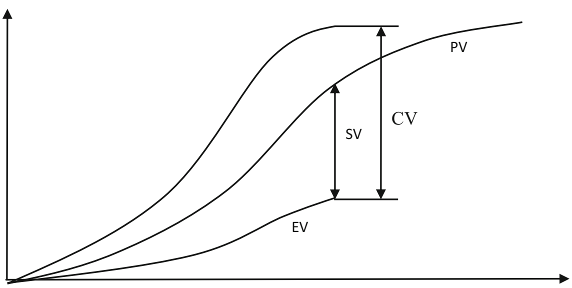


Fig. 119.1 Conceptual EVM graph

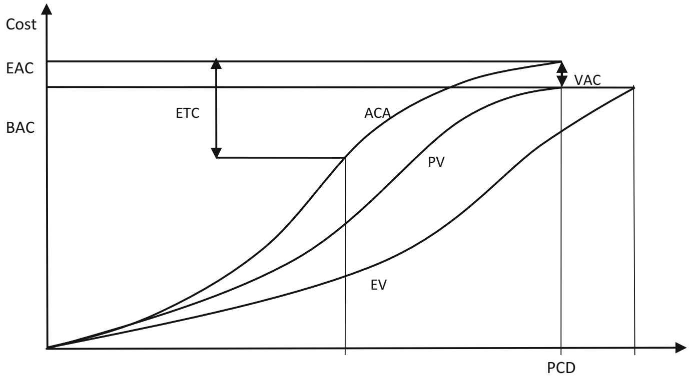


Fig. 119.2 Budget at completion, estimate completion date, planned completion date, estimate completion date, estimate at completion and variance at completion

- **EAC**: Estimate at completion.
- **Projected cost (EAC) according the initial budget**: Whether you are below or above the initial budget, the cost of the remaining work will be carried out as originally budgeted.

$$\mathrm{EAC} = AC + (\mathrm{BAC} - EV). \tag{119.6}$$

- **Projected cost (EAC) according to current CPI**: Regardless of the efficiency or inefficiency in resource use, costs of the remaining work will maintain the same level of efficiency or inefficiency, it is expected that the project has experienced the date continue in the future.

$$\mathrm{EAC} = AC + (\mathrm{BAC} - EV)/\mathrm{CPI}. \tag{119.7}$$

- **Projected cost (EAC) according CPI and SPI**: The corresponding to the ETC work will be done according to a ratio of efficiency that takes into account both the rate of cost performance (CPI) and the index of schedule performance (SPI), schedule delays also affect costs.

$$\mathrm{EAC} = AC + (\mathrm{BAC} - EV)/(\mathrm{CPI} \times \mathrm{SPI}). \tag{119.8}$$

- **Variations of this method measures the CPI and SPI**: According to different weight values, which are in the opinion of the project manager, for example, you can take 70 % of CPI and 30 % of SPI.
- **Projected cost (EAC) based on new estimates**: The new estimates allow more precise estimates, but it is a much slower method. It consists add the actual cost (AC) the present value of the remaining tasks.

$$\mathrm{EAC} = AC + (\mathrm{BAC} - EV)/(\mathrm{CPI} \times 0.7 + \mathrm{SPI} \times 0.3). \tag{119.9}$$

- **ETC**: Estimate to complete

$$\mathrm{ETC} = \mathrm{EAC} - AC. \tag{119.10}$$

- **VAC**: Variance at completion.

$$\mathrm{VAC} = \mathrm{BAC} - \mathrm{EAC}. \tag{119.11}$$

When the VAC is negative, then the project is over the planned budget, and if it is positive then the project is under planned budget.

$$\mathrm{VAC\%} = (\mathrm{VAC}/\mathrm{BAC}) \times 100. \tag{119.12}$$

The original EVM has been modified to adapt the necessities of present projects. The Earned Schedule Management (ESM) is an EVM extension that tracks program schedule in units of time rather than units of budget [9–11]. The Earned Duration Management (EDM) is an EVM extension which is more effective to manage the schedule that EVM and ESM [7]. The Quality Earned Value Management (QEVM) includes the quality component [6].

119.2 The Earned Schedule Management

ESM is more effective to evaluate the program schedule performance that the EVM. Earned Schedule (ES) identifies the time at which the amount of EV accumulated should have been earned. ES uses time-based indicators and performance indicators, and also metrics to provide schedule variance and performance efficiency management information in order to analyze the program progress against the budgeted plan. ES provides schedule performance results to support the program manager in the successful completion of a program [9–11].

In ESM, the performance indicators EV and Planned Value ($PV = EV$ when a program nears completion) are used to calculate ES, that is given by Eq. (119.13).

$$ES = t + (EV_{t+2} - PV_t) \,/\, (PV_{t+1} - PV_t)\,. \tag{119.13}$$

This equation uses the current EV and PV data values that are supplied in monthly CPRs.

The Schedule Performance Index, SPI(t), is the important performance metrics derived from the ES. SPI(t) shows the efficiency of a program in the performance of the schedule. This index is calculated with Actual Time (AT) and ES:

$$\mathrm{SPI}(t) = ES/AT. \tag{119.14}$$

ES incorporates time with the Planned Duration (PD) and SPI(t) values over the time (t) to calculate the final duration forecast. IEAC(t) is given by Eq. (119.15).

$$\text{IEAC}(t)_{ES} = PD/\text{SPI}(t). \quad (119.15)$$

The ES metrics lead EVM to use duration forecast methods in all of the project life cycle (early stage, mid stage and late stage).

119.3 The Earned Duration Management

The Earned Duration Management (EDM) is an EVM extension which uses cost and schedule indicators to monitor and analyze the project progress. The EDM was created to improve the shortcomings of ES for assessing the schedule performance of projects. The usage of time-based data for the generation of progress indicators is the basic concept of this method [7]. The EDM methodology uses the Total Planned Duration (TPD), which replaces PV and the Total Earned Duration (TED), which replaces EV:

$$ED = t + (\text{TED}_{t+2} - \text{TPD}_t) / (\text{TPD}_{t+1} - \text{TPD}_t)\,. \quad (119.16)$$

The ED schedule performance measures are shown in Table 119.5, together with those based on EVM/ES. There is a similarity between the equations for both sets of indicators (Fig. 119.3).

The Duration Performance Index, SPI(t), is a representation of how efficiently a program is performing to schedule. This index is calculated with Actual Duration (AD) and ED:

$$\text{SPI}(t) = ED/AD. \quad (119.17)$$

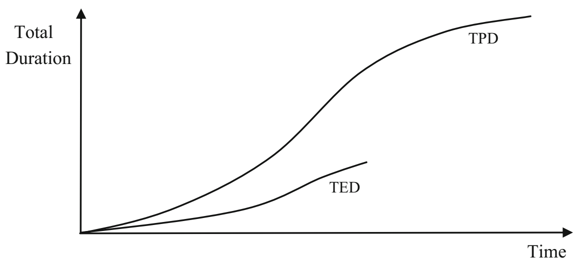


Fig. 119.3 Total planned duration and total earned duration

Table 119.1 Description of QEVM components [6]

Name	Description	Formula
Quality requirements (QR)	It is the quality requirements for a given task. The unit may vary according to the QR	
Quality performance index (QPI)	Indicates how efficient the project is conducted to meet the task's QR. It is used when a task has one quality requirement or as part of the Quality Index Number (QIN) when a task has more than one QR	$QPI = \begin{cases} 1, & \text{when the quality requirements are met} \\ 0, & \text{when the quality requirements are NOT met} \end{cases}$
Quality earned value (QEV)	The earned value of the work that met QR of the performed work. It is estimated by multiplying the QPI (or QIN) by the Actual Costs (AC) expressed in monetary units	$\mathrm{QEV} = \mathrm{QPI} \times AC$
Quality variance (QV)	Indicates the cumulative quality efficiency of the project	$QV = \mathrm{QEV} - AC$
Quality index number (QIN)	The ratio between the Sum of Quality Performance Index (QPI) for a given task, divided by the sum of the number of Quality Requirements (NQR) for a given task. It is used when a task has more than one quality requirement	$QIN = (\sum QPI)/(\sum NQR)$ $1QR = 1NQR$

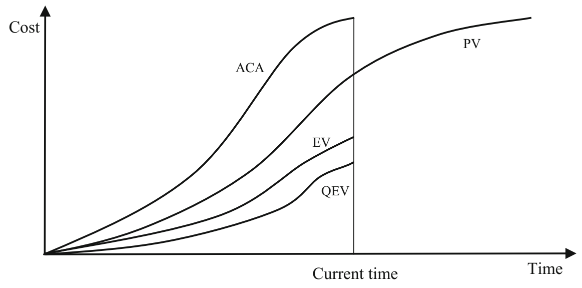
119.4 The Quality Earned Value Management

The Quality Earned Value Management (QEVM) is an EVM extension to include the quality component in this method. The QEVM aim is to show the project efficiency to deliver the project quality requirements based on the used time and spent money [6]. The main QEVM components are the Quality Requirements (QR), Quality Variance (QV), Quality Performance Index (QPI), Quality Index Number (QIN), and Quality Earned Value (QEV). Dodson [6] presented the third element of earned value management, where the main components are summarized in Table 119.1.

119.5 EVM in Aerospace Industry

Swedish Industry Group JAS (IG JAS) use EVM for the Gripen project (Saab JAS 39 Gripen, light single-engine multirole fighter aircraft manufactured). The Swedish Government was who decided the implementation of the EVM system for this project in 1982 [3] (Fig. 119.4).

Fig. 119.4 Planned value, actual cost, earned value and quality earned value



The EVM was applied by the National Aeronautics and Space Administration (NASA) to obtain a more efficient projects management, mainly for the project with budget constraints. An example of this was the STARDUST mission project. STARDUST was the Discovery Program's fourth mission [4]. With EVM and other management tools, the project and mission managers, Lockheed Martin Astronautics (LMA) and Jet Propulsion Laboratory (JPL), managed to complete on time with nearly $2M under budget. The project managers implanted efficiently the EVM and accomplish a reduction in time of evaluation of earned-value of a month to a week, allowing them to react quickly against deviations from the plan.

In 2004, Exploration Systems Mission Directorate of the NASA (ESMD) decided to implement a highly specific monthly EVM report in relatively small projects (budget from 1 to 10 million dollars) [12]. This implementation was not easy by the difficulty highly specialized language and the absence of adequate tool. ESMD used the NASA Program Management Tool (PMT) to implement a full set of EVM reporting capabilities. This tool was used by project managers for project planning and reporting and the data input templates was modified to generate the EVM reporting. This new tool (PMT EVM module) reduced the time to collect the cost and schedule data to one or two days, the project managers had more time for variance analysis and creating actions.

Department of Defense (DoD) is other US department which uses EVM as a management tool. The US Air Force F-22 fighter program is an example [5]. This project management methodology is used by big aerospace companies as Airbus and Boeing. The Boeing Company published in 1999 a manual Integrated Performance Management Practice, which had as scope to be used to implement EVM in all Boeing organizations. Boeing also collaborated with the National Defense Industrial Association to write the industry EVMS standard [1]. Bombardier also used EVM concepts for projects management [8].

Table 119.2 Planned value

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU	SEP	OCT	NOV	DEC
R1	0	0	0	0	0	0	0	0	0	0	0	0
R2	175	369	544	728	903	1097	1263	1351	1534	1738	1942	2078
R3	0	0	0	0	0	0	0	0	0	0	0	0
R4	50	107	157	210	261	317	365	390	443	502	561	600
R5	26	56	82	110	137	166	192	205	233	263	294	315
R6	885	1868	2753	3688	4573	5556	6397	6843	7769	8801	9834	10522
R7	1620	3420	5040	6750	8370	10170	11710	12525	14220	16110	18000	19260
R8	0	0	0	0	0	0	0	0	0	0	0	0
R9	42	89	131	175	217	264	304	325	369	418	467	500
R10	42	89	131	175	217	264	304	325	369	418	467	500
R11	0	0	0	0	0	0	0	0	0	0	0	0
R12	385	770	1155	1540	1925	2310	2695	2870	3080	3255	3430	3500
R13	0	0	0	0	0	0	0	0	0	0	0	0
R14	0	0	0	0	0	0	0	0	0	0	0	0
R15	252	533	785	1051	1304	1584	1824	1951	2215	2509	2804	3000
R16	21	44	65	88	109	132	152	163	185	209	234	250
R17	0	0	0	0	0	0	0	0	0	0	0	0
R18	0	0	0	0	0	0	0	0	0	0	0	0
R19	0	0	0	0	0	0	0	0	0	0	0	0
R20	21	44	65	88	109	132	152	163	185	209	234	250
R21	13	27	39	53	65	79	91	98	111	125	140	150
R22	0	0	0	0	0	0	0	0	0	0	0	0
R23	0	0	0	0	0	0	0	0	0	0	0	0
Rt	3533	6	1099	14656	18189	22072	25448	27208	30711	34559	38407	40925

119.6 The Model

119.6.1 Real Case Study

The planning values are given in Table 119.2. The current values are given in Table 119.3. Table 119.4 shows the earned values (Fig. 119.5).

119.6.2 Calculations and Results for the Decision Making

The model uses to evaluate cost and schedule date the parameters previously presented:

Table 119.3 Current value

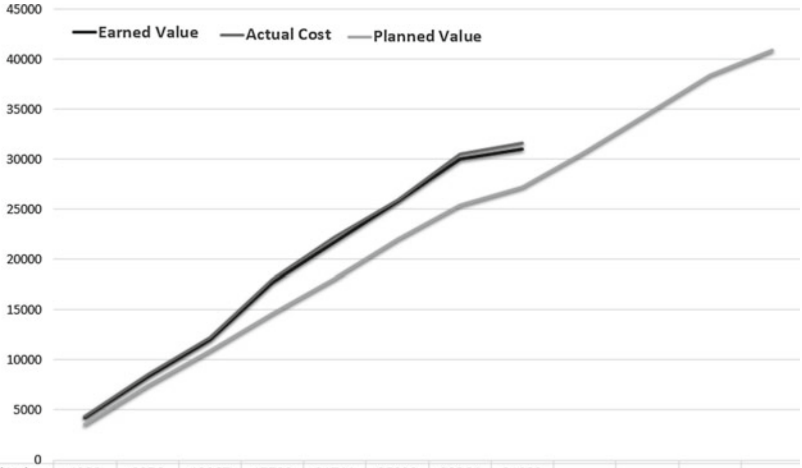
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU
R1	0	0	0	0	0	0	0	0
R2	297	642	881	1024	1113	1130	1176	1185
R3	0	0	0	0	0	0	0	0
R4	65	142	199	300	401	437	510	523
R5	15	15	15	93	120	148	190	199
R6	1110	2295	3217	4381	5073	6021	6800	7064
R7	1966	3707	5474	8852	11185	12735	15057	15615
R8	0	0	0	0	0	0	0	0
R9	0	0	0	47	47	47	146	148
R10	172	240	296	332	414	485	555	601
R11	0	0	0	0	0	0	0	0
R12	449	1066	1689	2476	3251	4128	5116	5196
R13	0	0	0	0	0	0	0	0
R14	0	0	0	0	0	0	0	0
R15	138	298	361	388	501	618	762	811
R16	20	39	68	83	89	98	128	128
R17	0	0	0	0	0	0	0	0
R18	0	0	0	0	0	0	0	0
R19	0	0	0	0	0	0	0	0
R20	0	0	0	0	0	0	0	0
R21	84	86	89	89	89	137	137	137
R22	0	0	0	0	0	0	0	0
R23	0	0	0	0	0	0	0	0
Rt	4316	8530	12289	18064	22282	25982	30575	31607

Table 119.4 Earned value

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU
R1	0	0	0	0	0	0	0	0
R2	292	630	866	1005	1113	1639	1706	1719
R3	0	0	0	0	0	0	0	0
R4	64	140	196	295	393	429	501	513
R5	15	15	15	91	118	145	186	195
R6	1090	2253	3159	4301	4981	5912	6676	7064
R7	1930	3640	5374	8691	10981	12503	14783	15615
R8	0	0	0	0	0	0	0	0
R9	0	0	0	46	46	46	144	146
R10	170	236	292	327	407	477	546	581
R11	0	0	0	0	0	0	0	0
R12	441	1047	1658	2432	3034	3853	4532	4209
R13	0	0	0	0	0	0	0	0
R14	0	0	0	0	0	0	0	0
R15	135	292	354	381	491	606	748	796
R16	19	38	66	81	87	96	126	126
R17	0	0	0	0	0	0	0	0
R18	0	0	0	0	0	0	0	0
R19	0	0	0	0	0	0	0	0
R20	0	0	0	0	0	0	0	0
R21	83	85	88	88	88	117	117	117
R22	0	0	0	0	0	0	0	0
R23	0	0	0	0	0	0	0	0
Rt	4238	8376	12067	17738	21741	25823	30064	31082

Table 119.5 Cost parameters (August 2015)

	CV	CPI	CV%	
R2	534.62	1.45	31	Under budged
R4	−9.33	0.98	−2	Over budget
R5	−3.73	0.98	−2	Over budget
R6	0	1	0	In budget
R7	0	1	0	In budget
R9	−2.66	0.98	−2	Over budget
R10	−19.13	0.97	−3	Over budget
R12	−987.22	0.81	−23	Over budget
R15	−15.27	0.98	−2	Over budget
R16	−2.34	0.98	−2	Over budget
R21	−20.33	0.85	−17	Over budget
Rt	−525.40	0.98	−2	Over budget



Earned Value	4238	8376	12067	17738	21741	25823	30064	31082				
Actual Cost	4316	8530	12289	18064	22282	25982	30575	31607				
Planned Value	3533	7416	10949	14656	18189	22072	25448	27208	30712	34559	38407	40925

Fig. 119.5 Case study: planned value, actual cost and earned value

Table 119.6 Schedule parameters (August 2015)

	SV	SPI	SV%	
R2	367.75	1.27	27	Ahead planned
R4	123.28	1.32	32	Delayed from planned
R5	−9.38	0.95	−5	Ahead planned
R6	221	1.03	3	Ahead planned
R7	3090	1.25	25	Delayed from planned
R9	−179.42	0.45	−55	Ahead planned
R10	256.21	1.79	79	Ahead planned
R12	1338.68	1.47	47	Delayed from planned
R15	−1154.84	0.41	−59	Delayed from planned
R16	−36.72	0.77	−9	Ahead planned
R21	18.97	1.19	19	Ahead planned
Rt	3873.51	1.14	14	Delayed from planned

Table 119.7 Resulted (August 2015)

	BAC	EAC	ETC	VAC	
R2	2078	1379	28	699	Under planned budget
R4	600	590	200	10	Under planned budget
R5	315	327	122	−12	Over planned budget
R6	10522	10414	3571	108	Under planned budget
R7	19260	18539	6014	721	Under planned budget
R9	500	953	628	−453	Over planned budget
R10	500	553	228	−53	Over planned budget
R12	3500	4599	1729	−1099	Over planned budget
R15	3000	6316	4365	−3316	Over planned budget
R16	250	292	129	−42	Over planned budget
R21	150	170	72	−20	Over planned budget
Rt	40925	40369	13161	556	Over planned budget

$$CV = EV - AC, \tag{119.18}$$

$$SV = EV - PV, \tag{119.19}$$

$$\mathrm{CPI} = EV/AC, \tag{119.20}$$

$$\mathrm{SPI} = EV/PC, \tag{119.21}$$

$$CV\% = (CV/EV) \times 100, \tag{119.22}$$

$$SV\% = (SV/PV) \times 100, \tag{119.23}$$

$$\mathrm{EAC} = AC + (\mathrm{BAC} - EV)/(CPI \times SPI), \tag{119.24}$$

$$\mathrm{ETC} = \mathrm{EAC} - AC, \tag{119.25}$$

$$\mathrm{VAC} = \mathrm{BAC} - \mathrm{EAC}. \tag{119.26}$$

Tables 119.5, 119.6 and 119.7 show the resulted of evaluation of project progress, the cost and schedule conclusions and the estimating project completion.

Acknowledgments This paper analyzed an earned value management approach to airspace engineering projects. The main characteristic of the model is the unit used to measure the cost, hours. Using hours as cost unit, the estimate at completion may be used as estimate completion date. Therefore the model provides the time required to complete the project with a cost estimation. And the cost (in hours) converts in monetary unit applying the price of the hour. The different resources ($R1$, $R2$,. . .) have different prices, these resources are department grouped by skills and competences.

References

1. Abba W (2000) How earned value got to primetime: a short look back and a glance ahead. In: Project management institute seminars and symposium in Houston, TX
2. Anbari FT (2003) Earned value project management method and extensions. Proj Manag J 34(4):12–23

3. Antvik S (2001) Why was earned value management important to the Swedish government in the gripen project?
4. Atkins KL, Martin BD, Vellinga JM, Price RA (2003) Stardust: implementing a new manage-to-budget paradigm. Acta Astronautica 52(2):87–97
5. Dibert JC, Velez JC, Dibert JC, Velez JC (2006) An analysis of earned value management implementation within the F-22 system program office's software development
6. Dodson M, Defavari G, de Carvalho V (2015) Quality: the third element of earned value management. Procedia Comput Sci 64:932–939
7. Khamooshi H, Golafshani H (2014) EDM: earned duration management, a new approach to schedule performance management and measurement. Int J Proj Manag 32(6):1019–1041
8. Laporte CY, Doucet M et al (2007) Improvement of software engineering performances an experience report at bombardier transportation—total transit systems signalling group
9. Lipke W (2003) Schedule is different. Meas News, 10–15
10. Lipke W (2013) Earned schedule-ten years after. Meas News (3):15–21
11. Lipke WH (2009) Earned schedule: an extension to earned value management–for managing schedule performance. Lulu Publishing, Raleigh
12. Putz P, Maluf DA et al (2007) Earned value management at NASA: an integrated, lightweight solution. In: 2007 IEEE aerospace conference, IEEE, New York, pp 1–8

Chapter 120
Fuzzy Comprehensive Evaluation Model for Flight Safety Evaluation Research Based on an Empowerment Combination

Fumin Deng, Chunqing Wang and Xuedong Liang

Abstract There are many factors on different levels which affect aircraft flight safety evaluations as there are many uncertainties and significant mutual interference between the level's, so it is difficult to attain accurate measurements. In consideration of these flight safety complexities, in this paper, a fishbone diagram is first used to analyze four main factors; the pilots, the aircraft, the environment and the management. We then introduce an innovative method called the 'Multi-factor Comprehensive Safety Risk Evaluation' which allows for the introduction of a more reasonable entropy weight by combining objective data and subjective expert preferences to decide the weight coefficients. These results are then combined with safety system engineering to develop a reasonable but fuzzy flight safety evaluation index by building a "combination empowerment—fuzzy comprehensive evaluation model". From the view of the "human-machine-environment-management systems theory", it is then possible to evaluate accident probabilities to ensure flight safety classification grading control. Finally, combined with the safety evaluation information and suggestions from airline personnel, the above model and method are verified.

Keywords Flight safety · Safety evaluation · Fishbone diagram · Combination empowerment-fuzzy comprehensive evaluation model · Human-machine-environment-management systems theory

120.1 Foreword

The purpose of a flight safety evaluation is to determine all the unsafe factors in the flight system and to identify the main or potential dangers to reduce the flight accident occurrence rate and to effectively improve flight safety. However, the flight safety system is a dynamic, multi variable and complex giant system, with the internal factors and risks often part of the state and some factors being difficult to

F. Deng · C. Wang · X. Liang (✉)
School of Business, Sichuan University, 610065 Chengdu, People's Republic of China
e-mail: liangxuedong@scu.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_120

quantify. Therefore, it is very difficult to use traditional evaluation methods to conduct objective and systematic flight system evaluations.

As guaranteeing flight safety is important for the sustainable development of a national civil aviation industry, flight safety risk research has been paid significant attention. Janic [3] used a causality and probability evaluation to evaluate the safety of a civil aviation system, and established a linear mapping relationship between accident factors and the consequences. Shi [6] used a fuzzy evaluation method to calculate the risk probability and severity of the safety risk assessment matrix, and used this to determine the flight safety risk assessment value. Gan [2] proposed a flight safety Relevance Vector Machine (RVM) evaluation method, which made use of the RVM model "black box" to create a simpler and more accurate flight safety evaluation. Wen [4] proposed an evaluation index system for aviation safety risk using an Analytic Hierarchy Process (AHP) to determine the evaluation index weights, to establish a flight safety risk assessment model based on a grey multi-level, and to evaluate the safety status of an airline company in China. Although there has been significant research which has examined flight safety problems and made important contributions to the flight safety risk level evaluations leading to improvements in passenger satisfaction, operational efficiency and innovation, However, in most cases, the weight of each factor was determined in advance or was very subjective, and the actual system needs to be viewed as a dynamic development process. Therefore, it is very difficult to achieve an objective and systematic evaluation using traditional evaluation methods. In addition, while research on safety evaluations is relatively mature, there has been significantly less research on flight safety risk assessment, which needs to consider the problems of multiple indices, ambiguity, and the mutual influences between each index. In view of this, this paper proposes an innovative expert subjective and objective weighting using a validity coefficient combined with a more reasonable weighting method to construct a "combination empowerment—fuzzy comprehensive evaluation model" for flight safety assessment, which not only avoids the problems mentioned above, but also considers the relative importance of the two different weights.

120.2 Establishment of Flight Safety Evaluation Index System

Based on airline safety operation management and implementation combined with the civil aviation companys safety assessment index system [8] and the security audit system index system used by the civil aviation administration in China, a method which combines fuzzy statistics from relevant expert opinions (government safety management personnel 1, pilots working in senior 1 safety management and security researchers 1) is developed, which identifies and eliminates the weaker correlations in the airline security risk assessment evaluation index, reviews the correlation between the evaluation index elements and allows for the construction of a fishbone analysis

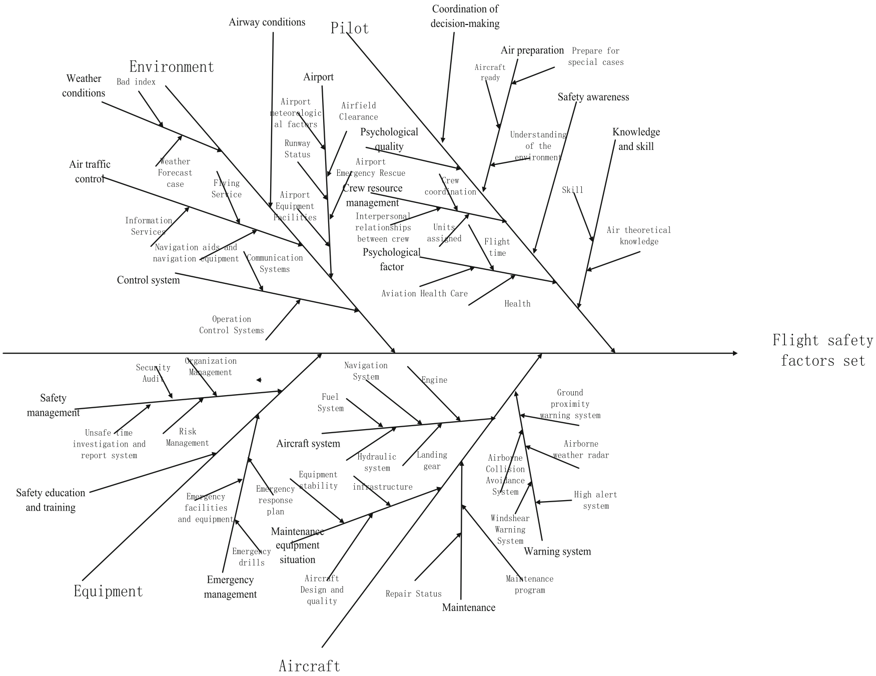


Fig. 120.1 Group conflict coordination framework for emergency decision

that focuses on the factors affecting flight safety, as shown in Fig. 120.1: As shown in Fig. 120.2, a comprehensive picture of the security risk situation at the airline company can be determined by an examination of the four main factors and the security within each factor layer. A comprehensive evaluation can be realized through the use of a fuzzy comprehensive evaluation method. The safety risk assessment of each factor is quantified using the safety assessment index system and relevant expert experience.

120.3 Entropy Weight Fuzzy Comprehensive Evaluation Model

120.3.1 Entropy Weight and Fuzzy Comprehensive Evaluation Model

In this paper, we use a multi-level fuzzy comprehensive evaluation to evaluate the lower levels firstly, and then to evaluate the higher level, finally we get the quantitative evaluation results by the weighted average formula [7]. With this weights combina-

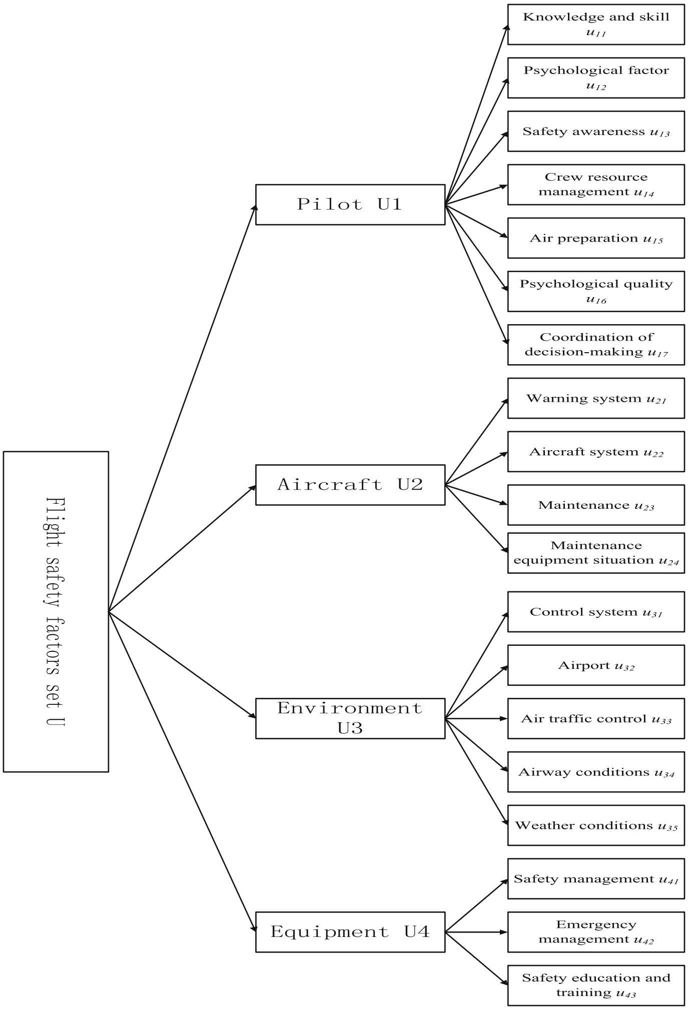


Fig. 120.2 Flight safety factor structural diagram

tion and the fuzzy comprehensive evaluation method, combined with safety system engineering considerations, we can evaluate the accident possibility from the perspective of the “human—machine—environment—management systems theory” to achieve a flight safety classification management and control instrument, the specific process for which is shown in Fig. 120.3.

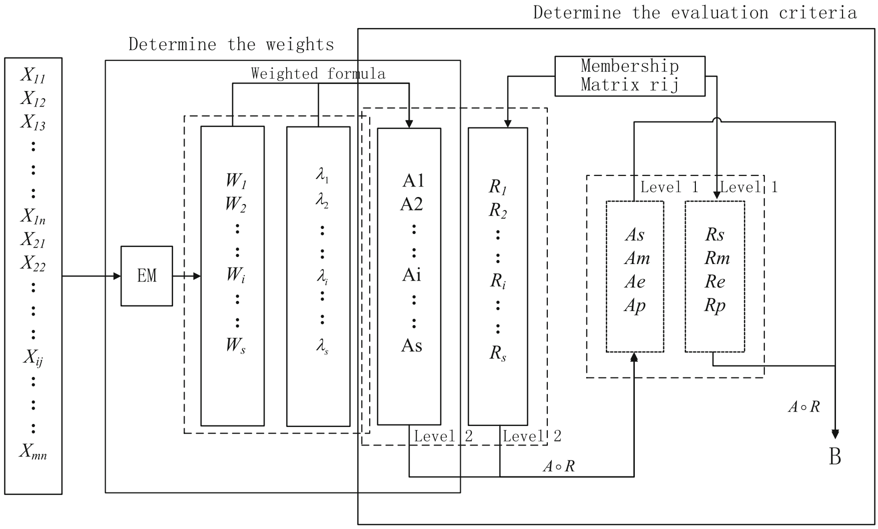


Fig. 120.3 Combination empowerment—fuzzy comprehensive evaluation model

120.3.2 Entropy Weight—Fuzzy Comprehensive Evaluation Model

Step 1. Establish flight safety evaluation factor set. U marked as: $U = \{u_1, u_2, \cdots, u_n\}$ is defined as the factors set that composes safety factors whose number is n. Through field research to collect relevant information on the master data to classify, organize and summarize, combined with expert interviews, collated sets of factors:

$$U = (U_1, U_2, U_3, U_4)\,, U_1 = (u_{11}, u_{12}, u_{13}, u_{14}, u_{15}, u_{16}, u_{17})\,,$$
$$U_2 = (u_{21}, u_{22}, u_{23}, u_{24})\,, U_3 = (u_{31}, u_{32}, u_{33}, u_{34}, u_{35})\,, U_4 = (u_{41}, u_{42}, u_{43})\,.$$

Step 2. Choose an evaluation set. Set evaluation set V to have m comments. $V = \{v_1, v_2, \cdots, v_n\}$, and v_j $(j = 1, 2, \cdots, m)$ refers to the flight safety evaluation of the jth level. Here, we select the evaluation sets $V = (v_1, v_2, v_3, v_4, v_5)$, from v_1 to v_5 as respectively referring to; outstanding, good, medium, low and poor.

Step 3. Build the comprehensive evaluation characteristic matrix. Assume that the candidate system for $Q = (q_1, q_2, \cdots, q_m)$, the comprehensive evaluation index system for $U = (u_1, u_2, \cdots, u_n)$, and the indicator for the candidate evaluation index with a characteristic matrix $X = (x_{ij})_{m\times n}$ refers to the following [1]:

$$X = \begin{pmatrix} x_{11} & x_{12} & x_{13} & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & x_{mn} \end{pmatrix}.$$

Of these, x_{ij} refers to evaluation scheme i for the evaluation of scale $j (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n)$.

Step 4. Characteristic matrix standardization. Here, we use a range transformation, which affects index standardization, as follows:

$$b_{ij} = \frac{x_{ij} - \min\limits_{1 \le i \le m} x_{ij}}{\max\limits_{1 \le i \le m} x_{ij} - \min\limits_{1 \le i \le m} x_{ij}}, \tag{120.1}$$

where $\max_{1 \le i \le m} x_{ij}$ and $\min_{1 \le i \le m} x_{ij}$ indicate the maximum and minimum value of the different objects in the same index standardization.

Step 5. From the entropy definition, determine the entropy value for the evaluation indices.

$$H_i = -\frac{\sum_{j=1}^{n} f_{ij} \ln f_{ij}}{\ln n}, \tag{120.2}$$

$$f_{ij} = \frac{b_{ij}}{\sum_{i=1}^{m} b_{ij}}. \tag{120.3}$$

Of these, $0 \le H_i \le 1$, $i = 1, 2, \cdots, m$; $j = 1, 2, \cdots, n$, when $f_{ij} = 0$, $f_{ij} \ln f_{ij} = 0$.

Step 6. Calculate the entropy weight of the first j entropy weight in the evaluation index which is defined as:

$$w_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i} \tag{120.4}$$

Of these, $w_i \in [0, 1]$ and $\sum_{i=1}^{m} w_i = 1$.

Step 7. Determine the comprehensive weighted index. Assume the m experts subjective weight vector to be the evaluation index, then combine this with the entropy weight to determine the comprehensive weight for:

$$a_i = (w_i + \mu\lambda_i) \Big/ \sum_{i=1}^{m} (w_i + \mu\lambda_i), \tag{120.5}$$

where a_i is the ith comprehensive weight in the evaluation indices, u is the subjective weight for the relative effectiveness of the objective weight coefficient, in which u sets the scope as $0.3 < \mu < 3$. If $u = 1$, and the subjective weight and objective weight are the same in the weights synthesis [5].

Step 8. Establish membership matrixes. Here, we combine the characteristics of the airline and comprehensive expert interview method after determining the average method to find the score for each index.

Excellent

$$ux = \begin{cases} 0, & 0 \leq x < 80, \\ (x-80)/10, & 80 \leq x < 90, \\ 1, & 90 \leq x \leq 100. \end{cases} \tag{120.6}$$

Good

$$u(x) = \begin{cases} 0, & 0 \leq x < 70, \\ (x-70)/10, & 70 \leq x < 80, \\ 1, & x = 80, \\ (90-x)/10, & 80 < x \leq 90, \\ 0, & 90 < x \leq 100. \end{cases} \tag{120.7}$$

Fair

$$u(x) = \begin{cases} 0, & 0 \leq x < 60, \\ (x-60)/10, & 60 \leq x < 70, \\ 1, & x = 70, \\ (80-x)/10, & 70 \leq x < 80, \\ 0, & 80 \leq x \leq 100. \end{cases} \tag{120.8}$$

Low

$$u(x) = \begin{cases} 0, & 0 \leq x < 50, \\ (x-50)/10, & 50 \leq x < 60, \\ 1, & x = 60, \\ (70-x)/10, & 60 < x \leq 70, \\ 0, & 70 < x \leq 100. \end{cases} \tag{120.9}$$

Poor

$$u(x) = \begin{cases} 1, & 0 \leq x < 50, \\ (60-x)/10, & 50 \leq x < 60, \\ 0, & 60 \leq x \leq 100. \end{cases} \tag{120.10}$$

Through the membership function affecting the flight safety factors, set U one by one in the u_i and determine the R_i membership matrix for the various factor sets U.

Table 120.1 The fuzzy evaluation set

Evaluation set V	Excellent (first-level)	Good (second-level)	Fair (third-level)	low (fourth-level)	Poor (fifth-level)
Scores	90	80	70	60	50

$$R = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nm} \end{pmatrix}.$$

Note: r_{ij} refers to the evaluation objects from the factors in the u_i to rank the membership degree of the fuzzy subset v_j, $(i = 1, 2, \cdots, n)$.

Step 9. Fuzzy comprehensive evaluation. Use the weighted average of the fuzzy operator "o" whose calculation steps are same with the multiplication of double matrixes to calculate the results between the membership matrix R and the weight matrix W, and it's detailed steps are as follows, fuzzy comprehensive evaluation results are obtained:

$$B = A \circ R = (b_1 b_2 \cdots b_m)\,, \tag{120.11}$$

in which B is a fuzzy subset of V on the evaluation set, and "o" indicates the fuzzy matrix synthesis calculations. According to the weighted average principle and the rank score, the B component processing and the quantitative guideline values, the final evaluation results can be seen to belong to a safe level (Table 120.1).

120.4 The Combination of Empowerment—Flight Safety Fuzzy Comprehensive Evaluation Model

120.4.1 Establishment of the Characteristics Matrix

Based on the flight safety evaluation factor set, the specific data indicators are gathered by the expert interview method and the standard data method, which determines the index weight. Using Eq. (120.1), each index was subject to standardization processing, as shown in Table 120.2: Using Eqs. (120.2) and (120.3), an evaluation of each index's entropy was conducted, as shown in Table 120.3: Using Eq. (120.4), the E1-7 weight vector was determined:

$W_1 = (0.2277, 0.1886, 0.0712, 0.2277, 0.1886, 0.3281, 0.1033)$.

Table 120.2 b_{ij}

i	1	2	3
Translation	mRNA[a]	22 (19–25)	Translation repression, mRNA cleavage
Translation	mRNA cleavage	21	mRNA cleavage
Translation	mRNA	21–22	mRNA cleavage
Translation	mRNA	24–26	Histone and DNA Modification

Table 120.3 H_i

Serial number	Index content	Entropy H_i
u_{11}	Knowledge and skill	0.3168
u_{12}	Physiological	0.4342
u_{13}	Safety awareness	0.7865
u_{14}	Crew resource management	0.7892
u_{15}	Air preparation	0.9676
u_{16}	Psychological factors	0.0155
u_{17}	Coordination of decision-making	0.69

Then, a table showing the various weight factors was derived, as in Table 120.5. The index weight vectors given by the experts were as follows:

$$\lambda_U = [0.4461, 0.2900, 0.0929, 0.1710] .$$

Each secondary index weight vector:

$$\begin{aligned}
\lambda_{U_1} &= [0.2872, 0.0805, 0.1131, 0.2064, 0.0982, 0.1027, 0.1119] , \\
\lambda_{U_2} &= [0.2876, 0.3179, 0.2876, 0.1069] , \\
\lambda_{U_3} &= [0.2120, 0.1087, 0.2120, 0.3587, 0.1086] , \\
\lambda_{U_4} &= [0.4231, 0.3124, 0.2645] .
\end{aligned}$$

According to type (120.3), take $u = 1$ as the available comprehensive weighting vector:

120.4.2 Establish Membership Function

Select the relevant experts to carry out the survey units. Organize expert evaluation results, after the normalization we can get the specific data according to the membership function such as Table 120.4:

Table 120.4 Membership Matrix

Serial number	Scores	The subordinate degree r_{ij}				
		Excellent	Good	Fair	Low	Poor
Knowledge and skill u_{11}	80	0	1	0	0	0
Psychological factor u_{12}	65	0	0	0.5	0.5	0
Safety awareness u_{13}	70	0	0	1	0	0
Crew resource management u_{14}	85	0.5	0.5	0	0	0
Air preparation u_{15}	70	0	0	1	0	0
Psychological quality u_{16}	85	0.5	0.5	0	0	0
Coordination of decision-making u_{17}	80	0	1	0	0	0
Warning system u_{21}	80	0	1	0	0	0
Aircraft system u_{22}	70	0	0	1	0	0
Maintenance u_{23}	55	0	0	0	0.5	0.5
Maintenance equipment situation u_{24}	60	0	0	0	1	0
Control system u_{31}	60	0	0	0	1	0
Airport u_{32}	70	0	0	1	0	0
Air traffic control u_{33}	80	0	1	0	0	0
Airway conditions u_{34}	60	0	0	0	1	0
Weather conditions u_{35}	70	0	0	1	0	0
Safety management u_{41}	85	0.5	0.5	0	0	0
Emergency management u_{42}	80	0	1	0	0	0
Safety education and training u_{43}	75	0	0.5	0.5	0	0

Table 120.5 Comprehensive entropy value method for the door crane weight value calculation in the evaluation indices at all levels of w

Environmental factor U_3	0.1138	Control system u_{31}	0.2035
Managerial factors U_4	0.2959	Airport u_{32}	0.0468
		Air traffic control u_{33}	0.1886
		Airway conditions u_{34}	0.2459
		Weather conditions u_{35}	0.3152
		Safety management u_{41}	0.3572
		Emergency management u_{42}	0.3371
		Safety education and training u_{43}	0.3057

120.4.3 Fuzzy Comprehensive Evaluation

The secondary factors were identified as; $u_{11} \sim u_{17}$ and $u_{21} \sim u_{24}$ and $u_{31} \sim u_{35}$, $u_{41} \sim u_{43}$ for the four primary factor weights U_1, U_2, U_3, U_4, as shown in Table 120.5.

Table 120.6 Entropy value method synthesis and the flight safety calculation process for all levels of the weight value A comprehensive evaluation index

Serial number	Weight A	Serial number	Weight A
Pilot U_1	0.4746	Knowledge and skill u_{11}	0.2575
		Psychological factor u_{12}	0.1346
		Safety awareness u_{13}	0.0921
		Crew resource management u_{14}	0.1383
		Air preparation u_{15}	0.0545
		Psychological quality u_{16}	0.2154
		Decision-making coordination u_{17}	0.1076
Aircraft U_2	0.1886	Warning system u_{21}	0.2704
		Aircraft system u_{22}	0.3531
		Maintenance u_{23}	0.2704
		Maintenance equipment situation u_{24}	0.1061
Environmental factor U_3	0.1033	Control system u_{31}	0.2078
		Airport u_{32}	0.0777
		Air traffic control u_{33}	0.2003
		Airway conditions u_{34}	0.3023
		Weather conditions u_{35}	0.2119
Managerial factors U_4	0.2335	Safety management u_{41}	0.3902
		Emergency management u_{42}	0.3247
		Safety education and training u_{43}	0.2851

From Table 120.6, the single factor membership degree was obtained. Then, from (10) the fuzzy judgment analysis set formulas were derived:

$U_1 = (0.1769, 0.4344, 0.2139, 0.0673, 0)$, $U_2 = (0, 0.2704, 0.3531, 0.2413, 0.1352)$, $U_3 = (0, 0.0777, 0.3800, 0.5101, 0)$, $U_4 = (0.1951, 0.6624, 0.1426, 0, 0)$.

So, then, the primary factors for membership matrix U were determined:

$$R = \begin{pmatrix} 0.1769 & 0.4344 & 0.2139 & 0.0673 & 0 \\ 0 & 0.2704 & 0.3531 & 0.2413 & 0.1352 \\ 0 & 0.0777 & 0.3800 & 0.5101 & 0 \\ 0.1951 & 0.6624 & 0.1426 & 0 & 0 \end{pmatrix}.$$

From Table 120.5, the primary factor weights were U_1, U_2, U_3, U_4, and by applying Eq. (120.10) the final airline flight safety assessment security results were determined.

$$B = (04746, 0.1886, 0.1033, 0.2335) = (0.1295, 0.4199, 0.1295, 0.4199, 0.0255).$$

By combining evaluation set $V = \{\text{excellent, good, fair, poor}\}$, and based on the maximum membership degree principles, it was concluded that the flight safety level was “fair”.

For every factor, the expert scoring of the membership function allowed for the calculation of the final flight safety factor results: the physiological score was 65 indicating a “fair” state, the engineering equipment, control system and route condition scores were all 60 indicating a “poor” state, the track maintenance score was 55, also indicating a “poor” state. Safety accidents caused by these factors need to be paid attention to by the airport unit, which should develop specific measures to improve the company’s safety management capability and the level of the safety in the flight systems to ensure the overall safety of the airline.

120.5 Conclusions

In this paper we introduced a new, more detailed flight safety evaluation system. The main features of the “combination empowerment—fuzzy comprehensive evaluation model” in this paper are:

(1) The use of a fishbone diagram, which included consideration of the pilot, plane, management and environment, for an initial inductive analysis can not only reflect the comprehensive integrity of a factor set in the flight safety evaluation system, but can also reflect the complete safety assessment process for the correlation between the various factors.

(2) Combining the differences in the objective weights and the arbitrariness in the subjective weights results in a more reasonable weighting which considers the relative importance of the two different weights, thereby avoiding the traditional use of expert experience and historical data weight assignment insufficiency and the use of an entropy weight method which does not reflect the importance of the indicators to the actual problem.

(3) From a systems engineering perspective, we used a “multiple risk factor comprehensive evaluation method” to build the combination empowerment—fuzzy comprehensive evaluation model ”. Accident probability was evaluated using the “human—machine—environment—management systems theory” view, and, by combining information from the subjective and objective evaluations, the subjectivity of traditional flight problem evaluation was reduced, ensuring a more accurate flight safety analysis.

References

1. Chi Z (2012) Research on models and methods of project risk assessment based on dea. Master’s thesis, Shenyang University of Technology, Shenyang (in Chinese)
2. Gan X (2012) Flight safety evaluation method based on relevance vector machine. J Saf Sci Technol China 8(12):143–148
3. Janic M (2000) An assessment of risk and safety in civil aviation. J Air Trans Manag 6(1):43–50

4. Jun W (2010) Airlines flight safety evaluation based on gray multi-level study. J Saf Sci Technol China 20(2):29–34
5. Lin J, Li T, Zhao Z (2012) Assessment on power system black-start schemes based on entropy-weighted fuzzy comprehensive evaluation model. Power Syst Technol 36(2):115–120
6. Rong S (2014) Based on the optimal combination of empowerment airlines flight safety risk assessment. J Transp Eng Inf Technol 12(2):36–41
7. Wang X, Li X (2008) Fuzzy comprehensive evaluation model of flight safety study. J Saf Environ 8(3):150–152
8. Weber (2000) China's general administration of civil aviation safety office. Tech. rep, Airline Safety Assessment System

Part VIII
Decision Making Systems

Chapter 121
A Study on the Macro Economic Antecedents and Trends of Mobile Banking Services in Bangladesh

Shibli Rubayat Ul Islam and Mohammad Tareq

Abstract Safe and reliable money transaction through regular banking system is not available for most people of Bangladesh as only 13 % of the 160 million people have banks accounts. People with no bank account used to send money through the slow and unreliable postal money transfer systems and by middlemen. One dramatic change in the life style of Bangladeshi people in recent time is the use of mobile phone. With the availability of cheap mobile phone sets manufactured locally and low call rates offered by the mobile operators, about 70 % people of the country use mobile phones. With this backdrop the mobile banking started in 2012 by Dutch Bangla Bank, but the full fledge operation took another couple of years. Currently about 18 mobile banks are providing mobile banking services to the people who are mostly out of the traditional banking service. The role of banking service on the economy is well researched. Past research shows that services provided by banks trough mobilizing savings, providing capital for business, and facilitating transactions are essential for economic development of a country. Though past studies shows that the traditional banking has a positive impact on economies apart from few notable exceptions there, is dearth of studies on the effect of mobile banking on the economy of a country. Especially in Bangladesh which started its full fledge mobile banking in 2014, there is few notable study that investigated the effect of mobile banking on economy of the country. Using twenty five months data, from January 2014 to January 2016 this paper investigates the macro-economic antecedents and trends in mobile banking services in Bangladesh. This study finds that the number of clients, number mobile banking agents and amount of transactions are increasing gradually. The result of the study shows that mobile banking cash-in and cash-out transactions are highly cointegrated which indicates a long run equilibrium relationship between cash-in and cash-out transactions in Bangladesh. One of the important finding of the study is that though most mobile banking service is improving gradually, inward foreign remittance are

S.R. Ul Islam (✉)
Faculty of Business Studies, University of Dhaka, 1000 Dhaka, Bangladesh
e-mail: shibli@du.ac.bd

M. Tareq
Department of Accounting and Information Systems, University of Dhaka, 1000 Dhaka, Bangladesh

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_121

not increasing during the study period and is volatile compared to other mobile banking services. Two factors were identified in the study as the antecedents of the mobile banking service i.e. growing economic need with the growth of the economy of the country and availability of mobile banking facility for mobile banking service. The contribution of the paper lies in the fact most people in Bangladesh is outside the traditional banking service and these people are now using banking service through mobile banking; however this area of research untapped yet. This expected that the finding of the study will bridge the gap in mobile banking literature and will help policy makers in formulating policy related to mobile banking.

Keywords Mobile banking · Economic development · Traditional banking · Electronic banking

121.1 Introduction

There are around 160 million people in Bangladesh with only 13 % of these people have bank accounts. Safe and reliable money transaction through regular banking system is not available for most people of Bangladesh. People with no bank account used to send money through the slow and unreliable postal money transfer systems and through by middlemen. One dramatic change in recent decade of the life style of Bangladeshi people is the use of mobile phones. With the availability of cheap phone sets and low call rates offered by the mobile operators, about 95 % use people of the country use mobile phone. With this backdrop mobile banking started in Bangladesh in 2012 by Dutch Bangla Bank with the full fledge operation from 2014. Currently about 18 mobile banks are providing mobile banking service to the people who are out of the traditional banking service. The role of banks in the economic development is well researched and agreed by past research. Past research shows that banks the services provided by banks trough mobilizing savings, providing capital for business, and facilitating transactions are essential for economic development of a country [1–6]. For example, Emmanuel and Adegboyega [3] study seeks to establish among others, the relationship between banking sector development in Nigeria and economic growth; the impact of regulation of banks on economic growth; the applicability of the financial repression hypothesis to Nigeria; and the direction of causality between banks and economic growth over a period of forty-one years. The results show that banks have significant positive impacts on growth in Nigeria under all the regulatory regimes.

Though past studies shows that the traditional banking has positive impacts on the economy of a country through mobilizing savings, creating capital, and facilitating transactions which improve the economy of a country, there is dearth of studies that investigated mobile banking effect the economy of a country. Especially the literature on Bangladeshi mobile banking is not tapped yet except few notable exception [7]. Khan et al. [7], however investigated the research questions related to the individual level factors (such as age, education and so on) that influence the adoption of mobile banking services in Bangladesh. Mobile banking services such as, cash in, cash out, money transfer, business to individual money transfer, bill payments among others have been helping the unbanked people of Bangladesh in getting the banking services for the last few years. How the mobile banking services have been used in the past years in Bangladesh? Is there any change in the usage of the banking services over the past years? What are the economic factors that influence the usages of the different mobile banking services in Bangladesh? These research questions are not studied and therefore unanswered in literature. This study will fill-up the gap in literature by shedding light on the above research questions. It is expected that this will help policy makers in formulating policy on mobile banking service.

121.2 Mobile Banking Service in Bangladesh

Mobile banking in Bangladesh started by Dutch Bangla Bank Limited (DBBL) in 2012 but the full fledge operation of mobile banking took another two years. Right now 28 banks have the license of doing mobile banking by their branches and many banks are waiting for authorization. Even though 28 banks have license but 18 banks are providing mobile banking services. The services which are provided by these mobile banks are as follows:

Cash-in The process for cash-in service starts with visiting a mobile banking agent by a mobile bank customer and then informing the agent the amount someone wants to cash in. The customer has to write down his/her account number and cash-in amount in the agent's register. Then she has to give the money to the agent. The agent will cash-in into the customer's account. Both the customer and the agent will get confirmation messages from the mobile bank in their mobile phones.

Cash-out Like cash-in customer has to visit a agent shop for cash-out service. The customer has to write down his/her account number and cash-out amount in the agent's register. Customer has to dial the cash-out number and need to enter all necessary information including the cash-out amount, agent number and code number. Then both the customer and the agent will get messages regarding the cash out. After that the agent will give the cash-out money to the customer.

Money Transfer Customers do not need to visit an agent for money transfer service. Customers can transfer money from their account to any other mobile bank account from anywhere. A customer has to dial a number and then enter the desired amount, receiver mobile banking account number, secret pin number among others. After this money will be sent; and both the sender and the receiver will receive a message regarding the money transfer. Receiver of the money can cash-out the money by visiting a agent shop.

Shopping The payment for shopping is very similar to money transfer. In this case the shoppers have to pay the merchants mobile bank accounts.

International Remittance Bangladeshis expatriates can remit through mobile banks agents overseas. For foreign remittance expatriates have to go to a mobile banks' enlisted exchange house or a partner bank. Customers need to fill out the remittance request form available at the enlisted exchange house or in the bank. The exchange house/bank will then send the money to receiver mobile bank account. The receiver can cash-out the foreign remittance by visiting an agent.

Other Mobile Banks Services Apart from cash-in, cash-out, international remittance, mobile banking customers can buy mobile phone talk time, pay utility bills, buy bus ticket and so on.

121.3 Methodology

To answer the research question of the study data were collected from Bangladesh Bank, the central bank of Bangladesh. As already mentioned in the earlier section of the paper, full fledge mobile banking in Bangladesh started from 2014. Therefore, data were collected for the last twenty five months, January 2014 till January 2016. For getting insight about the first few research questions, data were then analyzed by plotting these data in time series. To investigate the research question related to the macro-economic factors that affect the mobile service usage, Factor Analysis technique was used.

Factor analysis is one of the most popular multivariate statistical techniques. One of the primary goals of factor analysis is to identify latent factors. The relationship with observed variables and latent factors are expressed as "Factor Loading" in Factor Analysis. The mathematics of factor loading is as follows:

$$X_1 = \lambda_1 F + \varepsilon_1, \tag{121.1}$$

$$X_2 = \lambda_2 F + \varepsilon_2, \tag{121.2}$$

$$\cdots \tag{121.3}$$

$$X_m = \lambda_m F + \varepsilon_m. \tag{121.4}$$

Here, λ represents the Factor Loading, F is the latent factor and ε are the error terms.

121.4 Findings

This section of the paper details the result of the study. First it shows the different descriptive statistic related to mobile banking service providers and other information related to the mobile banking services in Bangladesh. After that it unveils how the mobile banking service changed over the years in Bangladesh. It then explores the economic factors that influence the mobile banking services in Bangladesh.

Table 121.1 presents the number of clients, active clients, number mobile banking agents and amount of transactions from January 14 to January 16. It shows that number of active clients during this time exceeded 13.6 million and it is growing days by day (see also Fig. 121.1) through the active and inactive clients are about

Table 121.1 Descriptive statistics of mobile service providers (January 2014 to January 2016)

Variable	Observation	Mean	SD	Min	Max
No of client	25	23700000	6078582	14000000	33100000
No of active Clients	25	9988520	2431727	5766000	13600000
Transaction per month*	25	11106.96	2927.096	6534.45	16745.27
No agents	25	478222.6	103437	208806	569656

*The amount is in crore Bangladeshi Taka (1 crore = 10 million)

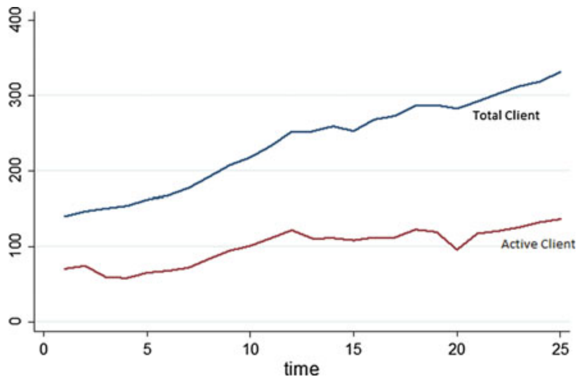


Fig. 121.1 Number of mobile banking clients from January 2014 to January 2016

double the number. Table 121.1 also shows that maximum transaction per month during these period exceeds 167.45 billion Taka (1 USD = 78 Taka) and growing gradually (see Fig. 121.2). These amounts of money are transacted through different ways: cash in, cash out, money transfer, business to individual money transfer, bill payments, foreign remittance, and so on. Table 121.2 shows the detail break-up of these transactions and Figs. 121.2 and 121.3 show the trend of these transactions.

The analysis of the data shows that the mobile banking cash-in and cash-out transactions are highly cointegrated (see Fig. 121.4). Johansen cointegration test was done and result shows evidence for this. This means that there is a long run equilibrium relationship between cash-in and cash-out transactions in Bangladesh. One of the important finding of the study is that though most mobile banking service is improving gradually sending foreign remittance are not increasing and is volatile compared to other services (see Fig. 121.5) (Table 121.1).

To investigate the economic factors that influence the mobile banking services in Bangladesh Exploratory Factor Analysis was done. Eigenvalue is used to determine how many factors are there in a Factor analysis. According to Kaiser criterion the number of factors to be retained in a Factor Analysis is factors which have Eigenvalue of equal or more than one. Therefore, based on the Kaiser criterion there are two factors in the data set of mobile banking service in Bangladesh. A scree Plot represents Eigen value on the Y axis and number of factors in the X axis. The scree plot of is presented in Fig. 121.6. The two factors of the study explain about 87.90 % variation

Table 121.2 Descriptive statistics related to mobile banking services in Bangladesh

Usage type	Observation	Mean	SD	Min	Max
Inward remittance	25	3.1928	0.5781185	2.54	4.58
Cash-in	25	4699.167	1226.057	2752.9	6969.25
Cash-out	25	4098.37	1036.983	2533.38	6128.01
p2p	25	1949.514	502.6262	1135.86	2862.69
b2p	25	81.6312	41.24904	28.94	157.79
Bill payment	25	108.528	37.49339	24.2	168.21
Others	25	165.5444	126.4041	22.4	509.07

All numbers are in crore Bangladeshi Taka (1 crore = 10 million)

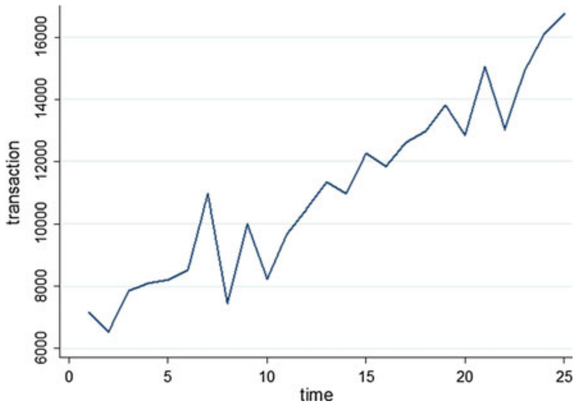


Fig. 121.2 Mobile banking transactions from the January 2014 to January 2016

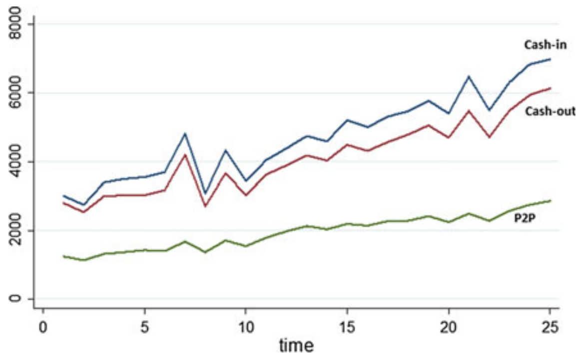


Fig. 121.3 Cash-in, Cash-out and P2P transactions from January 2014 to January 2016 (*the amount is in crore Bangladeshi Taka (1 crore = 10 million))

of the data. Table 121.4 presents the factor loading of the different mobile banking service in Bangladesh. It can be seen that most services are loaded with factor 1 except inward remittance and bill payment. These two are loaded with factor 2. The researchers identifies factor 1 as the growing economy of the country. As the

Fig. 121.4 b2p, bill payment, foreign remittance and other transactions from Jan 2014 to Jan 2016 (*the amount is in crore Bangladeshi Taka (1 crore = 10 million))

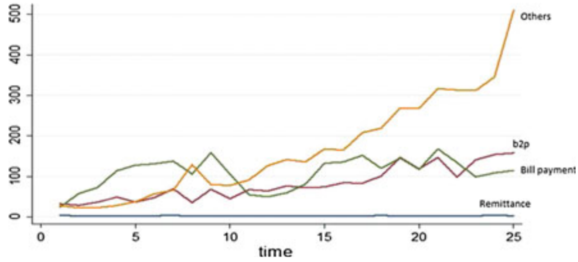
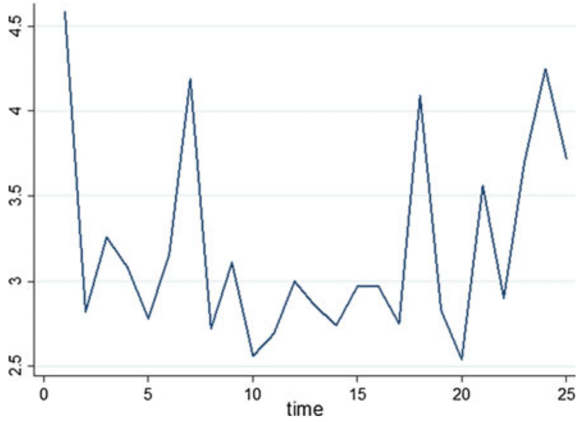


Fig. 121.5 Mobile remittance transactions from Jan 2014 to Jan 2016 (*the amount is in crore Bangladeshi Taka (1 crore = 10 million))



economy is growing the cash-in, cash-out, b2p and other mobile banking services are increasing.

Inward remittance and utility bill payment is loaded with Factor 2. Factor 2 perhaps is the availability of mobile banking services oversea. Though foreign remittance is growing over recent years in Bangladesh, remittance sending through mobile banking is not increasing. Moreover, utility bill payment does not have upward trend like most other services and is also loaded with factor 2. Therefore, these two mobile

Table 121.3 Eigen value table

Factor	Eigen value	Difference	Proportion	Cumulative
Factor 1	5.07570	3.99855	0.7251	0.7251
Factor 2	1.07714	0.40069	0.1539	0.8790
Factor 3	0.67646	0.57243	0.0966	0.9756
Factor 4	0.10403	0.04648	0.0149	0.9905
Factor 5	0.05755	0.04894	0.0082	0.9987
Factor 6	0.00861	0.00811	0.0012	0.9999
Factor 7	0.00051	–	0.0001	1.0000

Fig. 121.6 Scree plot

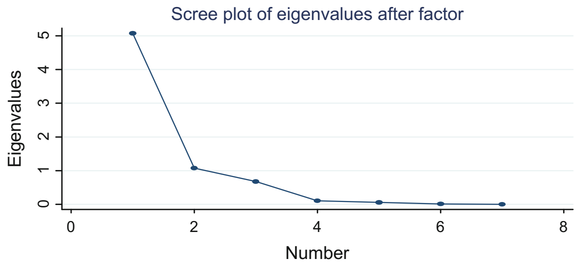


Table 121.4 Factor loading

Mobile banking service	Factor 1	Factor 2
Inward remittance	0.2995	0.8378
Cash-in	0.9940	0.0097
Cash-out	0.9928	0.0530
p2p	0.9705	−0.0324
b2p	0.9752	0.0199
Bill payment	0.4757	−0.6089
Others	0.9450	−0.0122

banking services are not loaded with factor 1, economic growth. Therefore, it may be concluded that factor 2 is availability of mobile banking service.

In an un-rotated solution of a factor analysis, the first factor describes most of variability in the data. This can be overcome with a rotated solution. The objective is to spread variability more evenly among factors. It can sometimes make sharper distinctions in the meanings of the factors. An orthogonal varimax rotation was done on the data of the study; however it did not change the factor loading result much. The rotated result is given in Table 121.5.

Table 121.5 Rotated factor loading result

Mobile banking services	Factor 1	Factor 2
Inward remittance	0.2700	0.8478
Cash-in	0.9930	0.0449
Cash-out	0.9904	0.0878
p2p	0.9710	0.0017
b2p	0.9739	0.0541
Bill payment	0.4968	−0.5919
Others	0.9449	0.0210

121.5 Conclusion

This paper investigates the macro-economic antecedents and trends in mobile banking services in Bangladesh. This study finds that the number of clients, number mobile banking agents and amount of transactions are increasing gradually. The mobile banking transactions in Bangladesh are mainly cash in, cash out, money transfer, business to individual money transfer, bill payments, and inward foreign remittance. The result of the study shows that mobile banking cash-in and cash-out transactions are highly cointegrated which indicates a long run equilibrium relationship between cash-in and cash-out transactions.

One of the important finding of the study is that though the volume of most mobile banking service is improving gradually, inward foreign remittance are not increasing during the study period and is volatile compared to other mobile banking transactions. This paper also investigates the antecedent of the mobile banking services in Bangladesh. Two factors were identified in the study as the antecedents of the mobile banking service ł growing economic need with growth of the economy of the country and availability of mobile banking facilities for mobile banking service.

The contribution of the paper lies in the fact most people in Bangladesh have been remain outside the traditional banking service and these people are now using banking service through mobile banking. But this area of research is untapped yet in Bangladesh. This expected that the finding of the study will bridge the gap in mobile banking literature and will help policy makers in formulating policy related to mobile banking.

References

1. Abramovitz M, Morris CT (1967) Society, politics and economic development: a quantitative approach. The Johns Hopkins Press, Baltimore
2. McKinnon RI (1973) Money and capital in economic development. Brookings Institution Press, Washington, D.C
3. Obademi EO, Elumaro A (2014) Banks and economic growth in Nigeria: a re-examination of the financial repression hypothesis. Am J Bus Manag 3(1):1–9
4. Porter RC (1966) The promotion of the banking habit and economic development. J Dev Stud 2(4):346–366
5. Schumpeter JA (1934) The theory of economic development: an inquiry into profits, capital, credit, interest, and the business cycle, vol 55. Transaction Publishers, New Brunswick
6. Shaw ES (1973) Financial deepening in economic development. Oxford University Press, New York
7. Khan SN, Akter M, Paul TA (2016) Factors influencing adoption and usage of mobile banking: Bangladesh experience. In: The 5th Asian management research and case conference. Springer, pp 16–18

Chapter 122
Impact of Military Spending on External Debt in Indebt Developing Countries: A Cross Country Analysis

Shariq Ahmed and Asif Kamran

Abstract This study is an attempt to evaluate the impact of military spending on external debt in highly indebted and low income developing countries. These countries are India, Pakistan, Brazil and Philippine. The above mentioned four countries have been characterized by the preponderant role of their military in economic matters. Major share of government expenditure consists of non-development expenditure. Big part of the government funds have been eaten up by the military spending. This study uses descriptive statistics, trend analysis and sophisticated poll regression technique using balanced panel data for the period 1988 to 2010 (annual data). Using dummy variable technique, the effect of military spending on external debt of individual country is also analyzed. Thus, it can be analyzed that the relationship is existing and are either consistent or not for all selected four countries. This consistency helps to identify the nature of relationship between the military spending and external debt.

Keywords World development indicator (WDI) · Gross domestic product (GDP) · External debt (ED) · Military expenditure (MB) · Tax revenue (TR)

122.1 Introduction

Brzoska [1] attempted to identify the fiscal and economic effects of various forms of arms transfer financing. He found that information of the spread of arms transfer as placed by International sources on the issue shows very less about real economic load. After the second world war and in the 1960s and 1970s when the cold war was on full swing military help and credit financing became bigger in all funding of arms import specially by developing countries. After the ending of this period, military aid levels had gone down very sharply but not very much in traceable on record about

S. Ahmed · A. Kamran (✉)
Management Science Department, Institute of Business and Technology, Karachi, Pakistan
e-mail: asifkamrankhan@gmail.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_122

credit financing. If the method of opportunity cost is employed that the borrowing due to arms was not increased as during 1980's, this depicts another sign that the arm trade became more profitable and commercial for these who were able and wanted to pay more for imports. Buyers with less deep pocket become less important for the makers of weapons and instead import used weapons or small arms. This difference increased in 1990s, thus the fiscal and economic aftermath of various kinds of arms transfer financing differ.

Looney and Frederickson in 1983 interrogated the potential effect, focusing on how military burden put effect on external borrowing of developing countries. They discovered that increase in military spending has a negative impact on the general welfare of such societies in the region which experience social and political disruption and are engaged in military role. The arm race minimizes the resources availability for importing capital goods that promote sustainable long-run prosperity.

Looney and Frederickson [2] examined the relationship between growth and defense spending in developing countries. They hypothesized that a negative relationship will exist between defense and economic growth in countries which are financially resource constrained, and a positive relationship will exist in countries which are relatively resource full and they are capable to meet the expenditure on this account. A factor and discriminate analysis are used to group countries. The variables chosen for the factor analysis depict a country's external debt, structural condition, growth, and balance of payments position. Regression equations were estimated for the total sample and each group, with the growth in Gross Domestic Product as the dependent variable. The results confirm the hypothesized positive relationship between defense and growth in the unconstrained group, but are not confirmed for the constrained group. The results suggest the importance of variables such as foreign exchange, net inflows of capital, external debt, and the growth of the public sector in general, on economic growth.

122.2 Literature Review

Dakurah, Davies and Sampat [3] tried to find the cause and effect relationship between military expenses and economic growth for 69 developing countries during 1975–1995. For the purpose, Granger causality testing was adopted that established some clues of one directional effects from military expenditure to growth and vice-versa as well as feedback relationship however, in major cases show no evidence of such nature. Furthermore examination of remaining plots of such cases established evidence of structural change in the data series. They came to this conclusion that the shortage of evidence of causal relationship between two arable in this study and other before it might be due to non-observance of basic exemptions in the testing, including but not limiting to the presence of structural breaks in data, the nature method of collecting data and the general lack of equilibrium condition in the macroeconomic environment in such countries. Dunne and Perlo-Freeman [4] estimated demand functions for developing countries before and after the end of the Cold War, they found little evidence of any change in the underlying relationship. One concern with their analysis was that the use of cross-section averages might have obscured important time series effects. The same issue also analyzed by Dunne and Sam [4]. However, they also deal with this issue by analyzing their data using static and dynamic panel data methods. This produces evidence of a change in relationship and suggests that the focus in the literature on cross-section analyses has indeed limited our understanding of important dynamic processes at work within countries.

Dunnet [5] is of the opinion that high public gap in relation to GDP potentially creates a vacuum for foreign loan and debt increase especially when the resources to gap this deficit locally are quite a view. When the economy is short of proper amount of foreign exchange, it tries to fill this gap by foreign borrowing and it also results in currency value depreciation which leads to increase in foreign exchange demands. There is every likely hood to be a relatively close relation between the deficits and foreign borrowing in developing countries, if the potential to use debt revenues to finance public expenditure is limited. The creation of money has already been misused considerably. Financial markets are weak and sources of domestic borrowing are relatively limited. Ali [6] analyzed the impact of military expenditure on inequality, controlling the arm forces, GDP growth, per capital income and other possible determinants. He used panel regression with country level data of the years 1987–1997 and obtain consistent estimates that there is a positive effects of military expenditure on pay inequality. Relationship is robust across variable definition and model specification. Given the close relationship between pay and income this result tells us that a country increase in military sphere could increase income inequality. Naryan in 2009 took the efforts to find nexus between military expenditure and economic growth but gave little importance to the impact on foreign debt of six Middle Eastern countries for period 1998–2002. The Middle East countries are the highest rates of arm imports in the world and on the same time this is the most indebted regions in the world. He used a panel unit route and panel co-integration framework and his analysis in forms that external debts is a elastic to military expenditure in the long run and inelastic in the short run. For the six Middle Eastern countries a 1 % increase in expenditure results in between a 1.1 and 1.6 % increase in external debt while a 1 % increase in term reduces external depending on the specific estimator employee. For the short run a 1 % increase in military expenditure increase external debt by 0.2 % effect of income on external debt is ecstatically insignificance.

122.3 Model and Methodology

This study is trying to find out an impact of military expenditure on external debt by using more appropriate balanced panel analysis of four low income countries from the period of 1988 to 2010. This study includes a new explanatory variable as tax revenue as percentage of GDP. Data has been taken from World Development Indicator 2011 about the following variables. All variables are in percentage form.

As data lack variation in the data of military expenditure in coinciding each country in a separate way, it is beneficial to amass or poll the cross country and time services data for a relatively homogenous group of countries that is countries having similarities in population, expenses and income etc. This problem can be minimized by employing varied approach in panel analyses such as fixed effect and random effect co-efficient estimators.

The pooled OLS Model:

$$ED_{it} = \alpha + \beta MB_{it} + \pi EX_{it} + \Omega GR_{it} + \prod \mathrm{TRES}_{it} + \delta TR_{it} + \mu_{it}, \quad (122.1)$$

where, in subscript, i and t are used for cross-sectional and time series respectively.

ED = External Debt Stock as percentage of GNI;
MB = Military Expenditure as percentage of GDP;
EX = Total Exports of goods and services as percentage of GDP;
GR = GDP Growth (annual %);
TRES = Total Reserves as percentage of GDP;
TR = Tax Revenue as percentage of GDP.

This analysis is an attempt to search the impact of military expenses on external debt by employing more appropriate balanced panel analysis of four low income countries from 1988 to 2010. This is an effort to gap the vacuum of this sort of field. This study also has a new explanatory variable as tax revenue as % of GDP. Data has been taken from World Development Indicator 2011 about the following variables. All variables are in percentage form. In order to examine the separate cross-sectional effects of military burden on foreign debt of each country another assumption is taken into account that there is a cross-section variation exists in slope co-efficient of military expenditure of each country.

The model of Fixed Effect approach (Keeping the assumption that all slope and intercept coefficients are constant but slope coefficient of military expenditure varies over individuals only).

$$\begin{aligned} ED_{it} = \alpha + \beta MB_{it} + \pi EX_{it} + \Omega GR_{it} + \prod \mathrm{TRES}_{it} + \delta TR_{it} \\ + \lambda_1 D_{1i} MB_{it} + \lambda_2 D_{2i} MB_{it} + \lambda_{3i} D_{3i} MB_{it} + \mu_{it}. \end{aligned} \quad (122.2)$$

D_1, D_2 and D_3 is dummy variables used as:
$D_1 = 1$ (For Pakistan) and 0 otherwise;
$D_2 = 1$ (For Brazil) and 0 otherwise;
$D_3 = 1$ (For Philippine) and 0 otherwise.

λ_1, λ_2 and λ_3 are differential slope coefficients. If λ_1 is significant then $(\beta + \lambda_1)$ is the slope coefficient of military expenditure variable for Pakistan (Fig. 122.1).

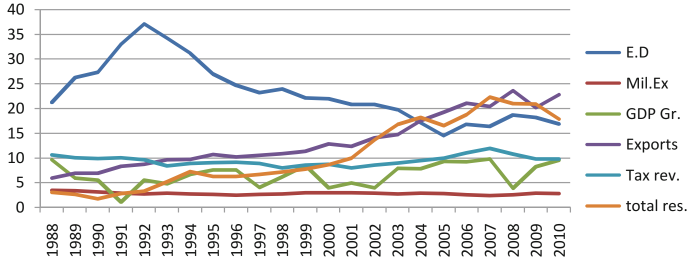


Fig. 122.1 India

122.3.1 Descriptive Analysis of Data

Table 122.1 indicates the trends of these variables period stretching from 1988 to 2010 in four countries. The analysis of these will help us to understand the relationship of external debt and military expenditures under specific economic circumstances.

In the case of India trends shows not such a significant relationship between military expenditures and external debt. The major cause of this is the augment in exports and foreign reserves and short run fluctuations in GDP growth and tax revenue but quit consistent in the long run. Another reason of this nexus is that India has maintained its military expenditures are quite constant as compared to its GDP and somehow it have a declining trend over the years but it is also interesting to see that military expenditures also shows the same declining trend.

Table 122.2 indicates in Pakistan context it also portrays a declining trend in external debt and military expenditure and also a significant relationship these two variables. This was partly due to low GDP growth and growth in exports and partly due to low tax to GDP ratio and slow growth in total reserves as compare to India (Fig. 122.2).

Table 122.3 indicates Brazil, trends of these variables are quite interesting especially in early years of the selected time period. From 1989 to 1991 shows quit worse economic situation in Brazil. In this period GDP growth decreased quit sharply even reached to negative figures tax revenue, exports and total reserves also show

Table 122.1 India

Period	EX. debt % GDP	Mil. exp % GDP	Exports	GDP gr.	Tax rev. % GDP	Total res.
1988	21.25837434	3.479115121	5.931205	9.627783	10.54638545	9185841796
1995	27.0173957	2.57596467	10.65708	7.574492	9.067803228	22864638483
2000	14.51715314	2.753583517	19.28015	9.284873	9.913767078	1.38E+11
2005	21.88461481	1.543097904	15.12836	3.159674	16.70867902	53799285065
2010	16.9006373	2.746884736	22.77126	9.552864	9.727842101	3.00E+11

Table 122.2 Pakistan

Period	EX. debt % GDP	Mil. exp % GDP	Exports	GDP gr.	Tax rev. % GDP	Total res.
1988	42.26563719	7.003371585	13.58642	7.625279	13.645899	1192694280
1995	49.38189791	6.002394527	16.70997	4.962609	13.24862454	2527544086
2000	44.82286367	4.024974707	13.44132	4.260088	10.08899115	2087167598
2005	30.00526999	4.046289552	15.6895	7.667304	9.604414425	11109359492
2010	31.26276574	3.248736767	13.55304	4.144241	9.995904704	17255566250

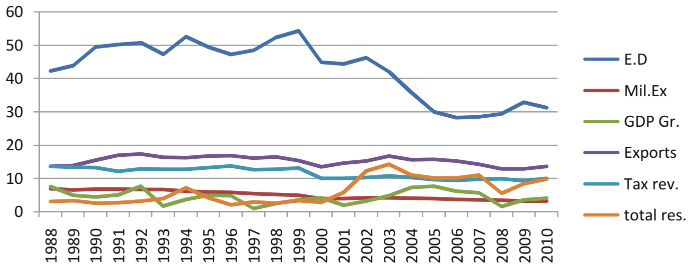


Fig. 122.2 Pakistan

Table 122.3 Brazil

Period	EX. debt % GDP	Mil. exp % GDP	Exports	GDP gr.	Tax Rev % GDP	Total res.
1988	37.01708363	2.128491016	10.88822	−0.10267	13.11277531	8090172124
1995	21.1732876	1.86213698	7.256807	4.416832	11.23687781	51477389634
2000	38.53891354	1.759501205	9.978194	4.308208	14.00387664	33015297296
2005	21.88461481	1.543097904	15.12836	3.159674	16.70867902	53799285065
2010	16.93260114	1.604234387	10.87159	7.533615	15.26699942	2.89E+11

a decreasing trend in this period. A sharp increase in military expenditures in this period becomes a major reason of increasing in external debt (Fig. 122.3).

Table 122.4 shows the context of Philippine it also shows a declining trend of external debt and military exports in the long run except during the period of 1995 to 2000 shows an increasing trend for external debt mostly due to decease in tax revenue and increase in exports. The above trends of these four countries to somehow explain the main point of the research that the impact of military expenditure is more in years of bad economic conditions then in batter economic environment (Fig. 122.4).

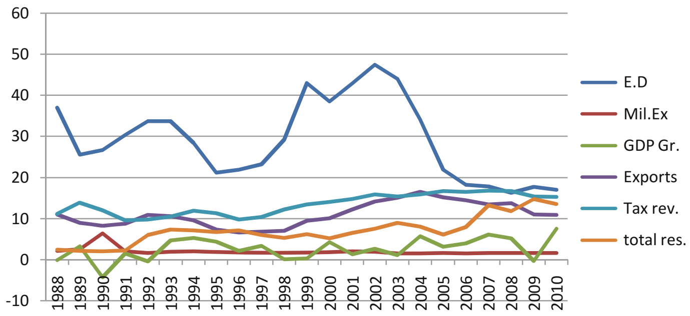


Fig. 122.3 Pakistan

Table 122.4 Philippine

Period	EX. debt % GDP	Mil. exp % GDP	Exports	GDP gr.	Tax rev. % GDP	Total res.
1988	78.89120938	2.458889214	28.39278	6.752544	14.17785402	2168908351
1995	51.50919671	2.294130332	36.35728	4.678692	16.29197183	7780875204
2000	71.98351632	1.608226684	51.36929	4.411213	12.84754896	15074070373
2005	59.99705215	1.331795207	46.13698	4.777663	12.4278107	18474495834
2010	36.18719495	1.22159432	34.80329	7.632264	12.14689213	62326282640

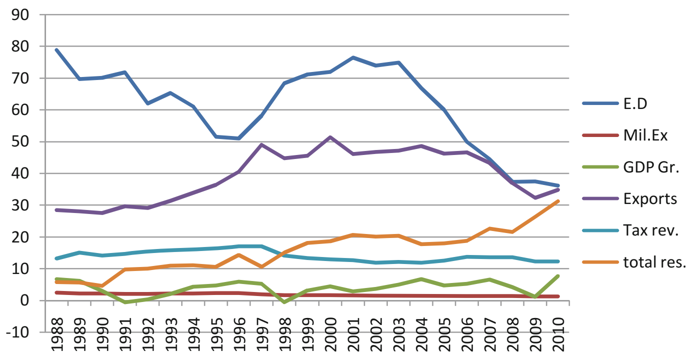


Fig. 122.4 Philippine

122.3.2 Results

Estimated results of model (122.1) are as follow

These result depicts the sign of the partial coefficients of all explanatory variables are according to the prior relation with dependent variable (External debt). All coefficients are measuring the elasticity with respect to external debt. Military expenditure expresses a significant positive impact on external debt at 5 % level of significance.

The coefficient of military expenditure shows a 1 % increase in elasticity will lead to 1.34 % increase in external debt, while other things remain unchanged. Exports show a positive relationship with external debt and are significant at 5 % and even 1 % level of significant. Economic growth and total reserves as percentage of GDP show a negative relationship with external debt and are also significant at 5 % and even 1 % level if significance. Tax revenue as per of GDP depicts a negative relation with external debt but it is highly insignificant even at 10 % level of significance. But still it is being assumed as an important explanatory variable according to its theoretical relationship with external debt. It is not possible to estimate results using random effect model because for this approach, number of cross-sections must be greater than number of coefficients. Fixed effect approach is more appropriate for our analysis. While in estimating the results there was a problem of heteroscedasticity been deducted in cross-sectional variation. This problem has been minimized by white cross-sectional slandered error correction option, which may be availed of by professional economic software. So these results are based on fixed effect approved keeping in view all cross-sectional and slope coefficient effects fixed (Table 122.5).

In order to analyses the separate cross-sectional effects of military burden on foreign debt, we may take another assumption of fixed effect approach that these exists cross-section variation in slope co-efficient for each country. The results are tabled below as under:

The estimated results of Eq. (122.1) are as:

Equation of these result portrays the sign of the partial coefficients of all explanatory variables are according to the prior relation with dependent variable (External debt). The sign of the coefficient of export is a debatable issue which will be discussed in concluding remarks. All co-efficient help measures the elasticity with relation to foreign debt. Military expenditure cast a positive significant impact on external debt at 5 % level of significance. The co-efficient of military expedite states a 1 % increase in elasticity will result to 1.34 % increase in military expenditure while other remain constant. Exports show a positive relationship with external debt and are significant at 5 % and even 1 % level of significant. Economic growth and total reserves as percentage of GDP show a negative relationship with external debt and are also

Table 122.5 The results of model 1

Variable	Coefficient	t-Statistic	Prob.
C	24.96621	4.245732	0.0001
MB	1.341527**	2.057841	0.0426
EX	1.566837***	15.07078	0
GR	−1.074348***	−3.073942	0.0028
TRES	−1.531948***	−7.28081	0
TR	−0.06259	−0.155678	0.8767
R-squared			0.790824
Adjusted R-squared			0.778663

significant at 5 % and even 1 % level if significance. Tax revenue as per of GDP shows a negative relation with external debt but it is highly insignificant even at 10 % level of significance. But still it is being considered as an important explanatory variable according to its theoretical relationship with external debt. It is not possible to estimate results using random effect model because for this approach, number of cross-sections must be greater than number of coefficients. Fixed effect approach is more appropriate for our analysis. While in estimating the results there was a problem of heteroscedasticity been deducted in cross-sectional variation. This obstacle has been removed by the white cross-section slandered error correction options available in professional economic software. All such results are founded on fixed effect approach keeping in the professional economic software. These results are based on fixed effect approach, keeping all (cross-sectional and slop coefficient) effect fixed. The intercept coefficient shows a common effect of all cross-sectional countries (Table 122.6).

To check the separate cross-sectional effects of military burden on external debt of each country we took another assumption of fixed effect approach that there is cross-section variation in slope coefficients of military expenditure for each country. The results are given as:

Tables 122.7 and 122.8 show that there is a significant cross-sectional variation in slope coefficients of military expenditure in context of India, Pakistan and Philippine and it shows insignificant negative impact of military spending on external debt in the context of Brazil. It is also interesting to see that in context of India it shows a significant positive impact of military spending on external debt. But in the context

Table 122.6 The result under the assumption of fixed effect approach

Variable	Coefficient	t-Statistic	Prob.
C	24.96621	4.245732	0.0001
MB	1.341527**	2.057841	0.0426
EX	1.566837***	15.07078	0
GR	−1.074348***	−3.073942	0.0028
TRES	−1.531948***	−7.28081	0
TR	−0.06259	−0.155678	0.8767
R-squared			0.790824
Adjusted R-squared			0.778663

*,**,*** are significant level at 10%, 5% and 1%, respectively

Table 122.7 Cross sectional effects

Variable	Coefficient	Std. error	t-Statistic	Prob.
C	41.90442***	3.541619	11.832	0
EX	0.938790***	0.183169	5.125265	0
GR	−0.958483***	0.352596	−2.718361	0.008
TRES	−1.187114***	0.193806	−6.125256	0
TR	−0.651213***	0.267195	−2.437215	0.0169

*,**,*** are significant level at 10%, 5% and 1%, respectively

Table 122.8 Cross country variation effect of military expenditure on external debt

Variable	Coefficient	Std. error	t-Statistic	Prob.
_IND–MB_IND	−2.215148***	1.005405	−2.20324	0.0303
_PAK–MB_PAK	1.199022***	0.567381	2.113258	0.0376
_BRA–MB_BRA	−1.923049***	1.300082	−1.479175	0.1429
_PHIL–MB_PHIL	8.001547***	3.332731	2.400898	0.0186

*,**,*** are significant level at 10%, 5% and 1%, respectively

of Pakistan and Philippine it shows a positive significant impact of military burden on external debt. In this approach all explanatory variables are statistically significant (including Tax revenue).

122.4 Conclusion

This paper is an effort to discover the existence of any significant bearing of military expenditure and external debt under some specific constant economic parameters. We can safely say that this attempt is a successful one in finding and tracing a significant relationship of military expenditure on external debt in low income countries. The trends of studied variable shows that the impact of military spending is significant in bad economic conditions but in good economic conditions such as in the years of increasing trend of GDP growth, Tax revenue, Exports and foreign reserves, military spending did not put any significant impact on external debt. But these trends represents are not so clear any shows a very constant trend for military burden over the years. The main reason of this is that these trends show trends of the studied variables for each country separately. In order to remove this problem pool data technique has been used to establish to inquire whether any significant relationship is in existence between military expenditure and external debt or otherwise. The outcomes of pool regression model, depending on fixed effect approach establish a significant positive impact of military spending on external debt. The results also shows sign of all the coefficients of explanatory variables are almost according to the economic theory. Positive sign on exports is of some contradictory nature as a negative impact was very much expected. But it may be possible that increase in exports may lead to increased imports of capital and so lead to the positive effect as what results show. GDP growth, Tax revenue as percentage of GDP and total reserves as percentage of GDP shows a negative relationship with external debt which has a good economic sense. In periods of consistent GDP growth, batter tax-to-GDP ratio and huge amount of foreign exchange reserve, a country have better options to fund its military expenditures then to borrow from abroad. All the explanatory variables are significant with respect to external debt except tax revenue as percentage of GDP. But to somehow it helps in understanding more better and true relationship between military spending and external debt under some specific economic framework. It also gives some understanding about the true relationship between external debt and tax revenue and it is beneficial to consider it as important explanatory variable. In this paper we also analyze the cross-sectional variation impact of military expenditure on external debt. In this attempt we find some interesting results which shows that there is a positive significant impact of military expenditure on external debt in the context of Pakistan but the results also revealed that there is negative but insignificant impact of military expenditure on external debt in the context of Brazil and a negative significant impact of military expenditure on external debt in the context of India. These structural disparities are due to different macroeconomic framework among these countries. The base of a significant negative relationship in the framework of India is most likely because of better foreign reserves, rapid growth in exports and high economic growth relative to the three countries. In the later approach Tax revenue as percentage of GDP also has become statistically significant including all other explanatory variables. This paper will help the policy makers to think on some new concepts and solutions about this emergent and decisive problem of increasing external debt in low income, low resources and less developed countries.

References

1. Brzoska M (1983) Research communication: the military related external debt of third world countries. J Peace Res 20(3):271–277
2. Looney RE, Frederiksen PC (1986) Defense expenditures, external public debt and growth in developing countries. J Peace Res 23(4):329–337
3. Dakurah AH, Davies SP, Sampath RK (2001) Defense spending and economic growth in developing countries: a causality analysis. J Policy Model 23(6):651–658
4. Dunne JP, Perlo-Freeman S et al (2003) Military expenditure and debt in small industrialised economies: a panel analysis. Def Peace Econ 15:125–132
5. Wilson R, Black W (2004) Essays in economic development and conflict. Ph.D. thesis, The University of Texas at Austin, TX
6. Ali HE (2007) Military expenditures and inequality: empirical evidence from global data. Def Peace Econ 18(6):519–535

Chapter 123
The Impact of Mutual Fund Ranking on Risk Adjustment

Kun Li, Han Chen, Youxin Zhang and Jay Lu

Abstract Using the panel data of China's equity mutual funds from 2008 through 2012, the paper investigates the relationship between mutual fund ranking and fund mangers' risk-taking behavior. We find that fund managers with poorer mid-year performance tend to increase their funds' risk in the latter half of the year. Furthermore, we find that fund managers' risk adjustment behaviors are affected by the market situation, and managers adjust fund risk more substantially in a market downturn.

Keywords Fund managers · Mutual fund performance · Fund risk-adjustment

123.1 Introduction

Although the fund industry started in China only one and a half decade ago, mutual funds have now become the most important institutional investors in China's stock market. Fund managers play a key role in determining the performances of the funds. Mutual fund companies usually adopt a performance-based compensation scheme to incentive fund managers, with the core evaluation criteria being the performance ranking of mutual funds. So it is important to know how fund managers react in response to the current incentive mechanism, especially when they perform poorly in the previous period.

Researches show that compensation incentives and employment incentives to fund managers have a significant impact on the risk adjustment of mutual funds. These studies report three major findings. First, fund managers prioritize compensation incentives in a bullish market, and those managers with a poor midyear performance are more possible to increase their funds' risk for the next half of the year, relative to managers with a good midyear performance. Second, fund managers prioritize employment incentives in a bearish market, and those managers with a poor midyear performance tend to increase their funds' risk to a lesser extent in the next half year,

K. Li · H. Chen (✉) · Y. Zhang · J. Lu
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: chenhanlc@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_123

relative to managers with a good midyear performance. Third, the more bullish the market appears, the more possible it is for the fund managers with a poor interim performance to adjust the risk level of the portfolios, relative to managers with a good interim performance. The opposite is true in a bearish market [5–7].

In recent years, numerous studies have been conducted on the relationship between mutual fund ranking and fund mangers' risk-taking behavior in the Chinese market. Shan [10] found that fund managers with low rankings tend to increase their risk more, however, this does not effectively improve the fund's performance; on the contrary, the increased risk may even lead to a worse performance in a bearish market. Xiao [3] came to the same conclusion. Cai [3] further indicated that the incentives of compensation and reputation can also have an impact on risk adjustment. In a bull market, the compensation incentive is in the dominant position with an accompanying competitive effect, while in a bear market, reputation incentive is the dominant incentive, with no competitive effect. Ma and Zhang [9] found that the performance ranking competition may produce incentive effect to managers by changing the fund investor behaviors.

The existing studies on the risk-adjustment behavior of fund managers in the Chinese market have not fully examined the tournament effect in different market situations, and the validity of the conclusions of existing researches is also limited because most of them examine the market before 2010 and use the fixed effect model. The purpose of our paper is to provide an update and shed more light on the risk-adjustment behavior of fund managers in the Chinese market. The main contributions of this study are as follows: (1) analyzing a larger and updated sample database of equity mutual funds from 2008 through 2012; (2) using the Sharpe ratio, Alpha value, and Treynorratio at the same time to measure the performances of mutual funds; (3) using a random-effect model.

The remainder of the paper is organized as follows. Section 123.2 discusses the mutual fund ranking and the incentives of fund managers. Section 123.3 is the research design. Section 123.4 presents our empirical results, and Sect. 123.5 summarizes our conclusions.

123.2 Mutual Fund Ranking and Incentives for Fund Managers

123.2.1 Mutual Fund Ranking

There were 1,173 securities investment mutual funds (hereinafter referred to as the "fund") in the Chinese market by the end of 2012. As both the variety and the quantity of funds are increasing rapidly, third-party evaluation has become an important reference for investors. The fund rating and ranking are two main components of

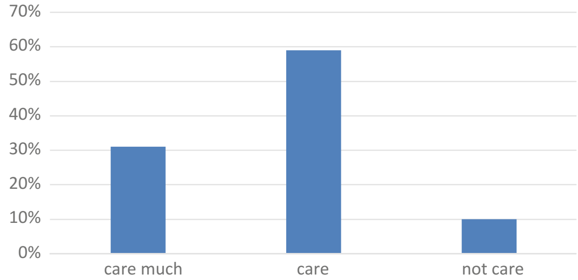


Fig. 123.1 The focus on fund performance ranking by individual investors in 2012

third-party evaluation. The fund rating is a classification of the overall performance of the fund during a certain period of time (such as return, professionalism, stability), and not as direct a category as fund ranking. The 2012 Annual Funds Investors Report shows that when investors choose a fund company, the fund performance and its ranking outweigh all other considerations, including the professionalism and stability of the fund management team. According to the Report, more than 90 % of investors focus on the fund performance ranking (Fig. 123.1), and choose funds based on the long-term performance of managers. This indicates that the performance-oriented fund ranking is most sought after by investors.

123.2.2 Incentives for Fund Managers

The compensation incentive is presently the main incentive for fund managers in China, and almost all mutual fund companies adopt a performance-based compensation scheme to incentivize fund managers, with the core evaluation criteria being the performance ranking of mutual funds. The scheme is as follows: Annual salary = basic salary + merit pay + hidden benefits.

Usually, the fund manager's basic salary and hidden benefits are not high, and it is the merit pay that makes a difference. Some data shows that mutual fund management companies generally distribute a 10–18 % of their profit after taxation as the merit pay to all fund managers. Of course, the core factor that determines the level of merit pay of each manager is the fund's performance ranking. We can take the example of the merit wages in a medium-sized fund company in Shenzhen. This company takes the ranking of the funds of the same size as standard. Then the managers whose funds are in the first 33 % of the same size funds ranking can earn a merit pay of 1,500,000 yuan annually; managers with funds of 33–50 % can earn 1,000,000 yuan; 700,000 yuan for 50–66 %; and 500,000 yuan for 66–80 %. There is no merit pay for the managers whose funds are in the last 20 % of the same category.

123.2.3 Risk Taking of Fund Managers

Based on the above analysis, we can conclude that fund performance ranking influences the investment choice of fund managers and even their risk taking behavior. To advance or maintain their rankings, they may make risky or conservative investment decisions for the next period. In particular, when the performance of the previous period is poor, fund managers may unreasonably increase their funds' risk for performance objectives with a bunker mentality. In that case, they sacrifice the interests of fund holders for their own merit pay and for company profit.

Therefore, it is necessary for us to explore the impact of fund performance ranking on the fund's risk adjustment. How will fund managers react to the ranking of the previous period?

123.3 Research Design

123.3.1 Variables

(1) The Dependent variable: Degree of Risk Adjustment (Ven)

The degree of risk adjustment is the dependent variable in this study. In existing researches, the following two measurements are used: the first measurement is $\frac{\delta_{it}^2}{\delta_{it}^1}$, which is the ratio between the fund risk in the previous and following periods; and the second measurement is $\delta_{it}^2 - \delta_{it}^1$, which is the risk difference between the previous and following periods. In this article, we use the second measurement, that is:

$$Ven = \delta_{it}^2 - \delta_{it}^1.$$

In the equation above, δ_{it}^1 is the fund risk during the first half year, δ_{it}^2 is the fund risk during the second half year.

(2) The Independent Variable: The Ranking of Fund's Relative Performance (Rank)

To more completely reflect the relationship between fund performances and fund risk, we adopt multiple indicators, i.e., Sharp ratio, Alpha value and Treynor ratio to measure fund performances. In empirical tests, we use the fund's relative performance ranking (Rank) to evaluate the fund performance in the first half of the year. The relative performance ranking is obtained by ranking all funds according to the data of a certain index at the same time point. Then we calculate the percentile rank of a fund relative to all funds in accordance with the ranking, and the range of the percentile rank is (0, 1]. A smaller the value indicates a better fund performance.

(3) Controlled Variables

We add seven controlled variables in order to remove the impact of other factors on fund managers' risk adjustment behavior, and these factors are informed by previous researches.

① The Situation of the Stock Market (Mark)

The degree of funds' risk largely depends on market situation. Thus, fund managers may pursue different risk adjustment strategies in different market conditions. Therefore, we introduce market situation as a controlled variable to avoid its impact on risk taking behavior. It contains two types of market (a bull market and a bear market) and they are distinguished by the return of the Shanghai and Shenzhen 300 Index (CSI 300 Index). When the return of the CSI 300 Index is positive during the first half of the year, it is considered to be a bull market; when the converse is true, a bear market prevails. We define this polarity as "1" for a bull market and as "0" for a bear market.

② The Size of Funds (Size)

The size of funds can impact the return of mutual funds and then impact the merit pay of fund managers. Besides, it is much easier to adjust the risk level of small funds rather than large ones [3]. The natural logarithm of the figure is used in the calculation to reflect the size of the funds.

③ The Age of Funds (Age)

Some studies find that compared to old funds new funds tend to adopt a more aggressive investment strategy to gain market recognition. Therefore, the degree of risk adjustment may be larger for new funds [2, 11]. For this reason, we add the fund age as a dependent variable.

④ The Change of Fund Managers (Man)

Dince, Gregory-Allen and Shawky [4] revealed significant differences in the risk adjustment behaviors of fund managers with different qualifications. Azmi [1] showed that the degree of fund risk adjustment will be higher if the managers are women rather than men. There are also studies suggesting that the overall risk of the fund's risk will be lower with an experienced manager. The change of fund managers may have an impact on the adjustment of fund risk and is used as a controlled variable. We define the changed fund manager as "1" and the unchanged fund manager as "0" in the period of observation.

⑤ The Size of the Mutual Fund Company (Corp)

The corporate governance is relatively more perfect and fund managers are more closely monitored in a large mutual fund company. Thus, We include the size of the mutual fund company as a controlled variable and use the natural logarithm of the net value of the fund assets under management to measure the company size.

⑥ The Proportion Holding by Institutional Investors (Inv)

In theory, institutional investors pay more attention to long-term interests than do individual investors. As a result, if institutional investors hold a large share in the fund, fund managers may prioritize long-term interests instead of aiming for short-term profits through risk adjustment. Therefore, we make the proportion holding by institutional investors a controlled variable (Table 123.1).

Table 123.1 The variables

Variable groups	Variables	Symbol	Definition
Dependent variables	Degree of risk adjustment	Ven	Risk of the second half year-risk of the first half year
Independent variables	Sharpe Ratio	Sharpe	The midyear percentile rank of Sharpe Ratio
	Alpha value	Alpha	The midyear percentile rank of Alpha value
	Treynor index	Tp	The midyear percentile rank of Treynor Index
Controlled variables	The market situation	Mark	Dummy variable,1 in a bull market and o in a beat market
	The size of funds	Size	Ln (the net asset value of the fund in midyear)
	The age of funds	Age	Ln (the date of observating-the date of establishment)
	The change of fund managers	Man	Dummy variable, changed to be 1, unchanged to be 0
	The size of mutual fund companies	Corp	Ln (the total net asset value of funds under management)
	The proportion holding by institutional investors	Inv	Shares holding by institutional investors/the total number of shares × 100 %

123.3.2 The Model

Based on above review of the literature, we will examine the relationship between the incentives for managers and fund risk adjustment by conducting a multivariate regression analysis as following:

$$\begin{aligned} \text{Ven} = &\alpha + \alpha_1 \text{Rank}_i + \alpha_2 \text{Mark} + \alpha_3 \text{Man} + \alpha_4 \text{Corp} + \alpha_5 \text{Age} \\ &+ \alpha_6 \text{Inv} + \alpha_7 \text{Size} + \varepsilon. \end{aligned} \tag{123.1}$$

Among them, “Ven” represents the degree of fund risk adjustment. is the intercept and α_1, α_7 are the coefficients. Here, “Rank_i” represents the incentives for managers. Also, $i = 1, 2, 3$, represent the Sharpe Ratio relative ranking, the Alpha value relative ranking, and the relative ranking of Treynor Index. “Mark” represents the type of the market situations. “Man” shows if the fund managers have been changed in the period of observation. “Corp” represents the total size of funds under management of the mutual fund company. "Age" represents the time since its establishment. "Inv" represents the proportion of shares holding by institutional investors and size represents the size of the funds asset. ε is the residual error.

123.4 The Empirical Results

123.4.1 Sample and Data

Our sample consists of the equity mutual funds in China established before December 31, 2007. We exclude funds investing in overseas equities, and there remain 117 eligible funds. Our sample period is from 2008 through 2012. The source of the data used in this research is from China Stock Market & Accounting Research Database (CSMAR).

123.4.2 The Descriptive Analysis of the Sample

Table 123.2 shows the sample means of each variable during the five years. There are three years when the sample funds increased the risk of the portfolios on average in the second half of the year, and there are two years of decreasing the risk of the portfolios. Three variables did not change much during the five years of observation period: the size of mutual fund companies; the proportion holding by institutional investors; and the average fund size. The order of Sharpe Ratio, Alpha value, and Treynor Index is not the same. In 2008, there appears Sharpe Ratio > Alpha value > Treynor Index. In 2012, however, there appears Sharpe Ratio > Treynor Index > Alpha value; simultaneously, both the Sharpe Ratio and Treynor Index in 2012 are higher than in 2008, but the Alpha value is lower than in 2008. This indicates that different measurements have a great impact on the relative performance ranking of funds. Thus it justifies the use of multiple performance indicators in our study to analyze the degree of risk adjustment of funds.

123.4.3 Single Factor Analysis

In order to examine the relationship between the incentives for fund managers and the degree of risk adjustment, we first build the following simple model:

$$\mathrm{Ven} = \beta + \beta_1 \mathrm{Rank}_i + \delta. \tag{123.2}$$

Table 123.2 The mean value information of regression sample

	Degree of risk adjustment	Size of companies	Proportion holding by institutional investors (%)	Size of funds	Sharpe ratio	Alpha value
2008	0.0486	6.0069	0.1022	22.5315	0.523	0.5114
2009	0.0238	6.1085	0.1033	22.5012	0.392	0.4496
2010	0.1417	6.0225	0.1136	22.299	0.5785	0.5329
2011	−0.0742	6.1637	0.1157	22.284	0.3563	0.3539
2012	−0.1086	6.1956	0.1169	22.0819	0.6071	0.3789

Table 123.3 The results of simple regression (section fixed effect)

Variable names	Rank		
	Sharpe Ratio	Alpha value	Treynor Index
Fund performance	0.1122***	0.1785***	0.1345***
C	−0.0489***	−0.0733***	−0.0560***

Note "***" means it is significant at the 1 % level

Among them, "Ven" is the degree of fund risk adjustment. β is the intercept; β_1 is the coefficient; "Rank_i" represents the incentives for managers. Also, $i = 1, 2, 3$, are the Sharpe Ratio relative ranking, the Alpha value relative ranking and the relative ranking of Treynor Index. δ is the residual error.

Table 123.3 shows the empirical results, and we can see that the coefficients are 0.1122, 0.1785, 0.1345 respectively for Sharpe Ratio, the Alpha value and the Treynor Index, and are highly significant. Overall, this shows a significant positive correlation between the incentives for fund managers and the degree of fund risk adjustment.

123.4.4 Multivariate Regression Analysis

In this part, we use Eq. (123.1) to make a multiple regression analysis on the degree of fund risk adjustment. The empirical results are shown in Table 123.4.

We can see that no matter which indicator (Sharpe Ratio, Alpha value or Treynor Index) is used to measure fund performance, the coefficients of fund performance, market situation and fund age are significant at the 1 % level, and the other four variables are not significant.

The most concerned explanatory variable in the research is the relative fund performance ranking. No matter which indicator is adopted (the Sharpe Ratio, the Alpha value or the Treynor Index), there emerges a highly significant positive correlation between the relative fund performance ranking and the degree of fund risk adjustment. The correlation coefficients are 0.1246, 0.1598 and 0.1538, respectively, which

Table 123.4 The results of the multivariate regression

Variable names	Rank		
Fund performance	0.1246***	0.1598***	0.1538***
Market situation	−0.0688***	−0.0611***	−0.0744***
Fund scale	0.0199	0.0177	0.0194
Fund age	−0.0164***	−0.0135***	−0.0157***
Managers changed or not	−0.0124	−0.014	−0.0134
Size of mutual fund companies	−0.0143	−0.0138	−0.0143
Proportion holding by institutional investors (%)	0.031873	0.031934	0.030293

Note "***" means it is significant at the 1 % level

indicates that the relative fund performance ranking of the first half of the year has a significant impact on the degree of fund portfolios' risk adjustment in the second half of the year. Moreover, the managers with a worse performance are likely to engage in more risk in the following period.

When comes to the controlled variables, the market situation and fund age are significant at the 1 % level. The market situation displays the most significant impact of all the controlled variables on the degree of fund risk adjustment. The correlation coefficients are −0.0688, −0.0611 and −0.0744, respectively, which indicates the managers are affected by the market situation when they adjust the risk of funds. Managers adjust fund risk more substantially in a market downturn. If the first half of a year is in a bearish market, the average interim performance of mutual funds is likely to be poor, then the majority of fund managers, eager to improve the coming performance evaluation, are more likely to increase the fund risk. This is logically identical with the former conclusion that the managers with a worse performance are likely to pursue more risk. In addition, the coefficient of the fund age is negative. This indicates that the shorter time the fund has been established, the more aggressive its investment strategy tends to be. Although there is a positive correlation between the proportion holding by institutional investors and the degree of fund risk adjustment, the impact is not significant. Similarly, there is no significant correlation between the risk adjustment and the variables such as managerial turnover, fund size, and the scale of fund management companies.

123.5 Conclusions and Suggestions

We find a significant correlation between the relative fund performances and subsequent risk adjustments. The fund managers with a low ranking tend to increase the risk of the fund portfolios in the second half year. They expect to earn higher profits with higher risk investment and improve their ranking. The managers with a higher ranking are usually not that aggressive and inclined to adopt a more consistent investment strategy with the first half year to maintain their advantage in the ranking. The findings of our paper have important implications both for mutual fund industry and for mutual fund investors. For the industry, first, the mutual fund companies, they should use multiple indicators for the evaluation of fund managers and improve the incentive mechanism rather than evaluate fund managers only with a short-term performance ranking; and second, the mutual fund companies should establish a sound system of internal risk control to avoid temporary changes of investment philosophy and aggressive investment behaviors. For the investors, they should be aware of the possible aggressive investment behaviors of fund managers with previous poor performance and prepare for a risk diversification and control.

Acknowledgments The author would like to acknowledge the financial support from the Project of Research Center for System Sciences and Enterprise Development (Grant No. Xq13B01), National Science and Technology Support Programme Project (2012BAH31F01), the Soft Science Project of Sichuan Province (2008ZR0140) and the Science and Technology Infrastructure Platform Project of Sichuan Province (2015JCPT0006).

References

1. Ahmed Azmi R (2008) Mutual funds performance: Does gender matter in an emerging market. Technical report, mimeo, University of Portsmouth
2. Brown KC, Harlow WV, Starks LT (1996) Of tournaments and temptations: an analysis of managerial incentives in the mutual fund industry. J Financ 51:85–110
3. Cai Q, Liu J (2012) Performance ranking, market condition and risk taking behavior of fund managers: struggling for fame or for wealth? Chin Rev Financ Stud 3:66–67 (In Chinses)
4. Dincer OC, Gregory-Allen RB, Shawky HA (2010) Are you smarter than a CFA'er? manager qualifications and portfolio performance. In: 23rd Australasian finance and banking conference
5. Hu P, Kale JRl et al (2011) Fund flows, performance, managerial career concerns, and risk taking. Manag Sci 57(4):628–646
6. Kempf A, Ruenzi S, Thiele T (2009) Employment risk, compensation incentives, and managerial risk taking: evidence from the mutual fund industry. J Financ Econ 92(1):92–108
7. Koski JL, Pontiff J (1999) How are derivatives used? evidence from the mutual fund industry (digest summary). J Financ 54(2):791–816
8. Kun Y, Cao H, Song S (2013) Star effect and bottom effect in flow-performance relationship: a principal agent analysis. J Manag Sci China 16(5):29–38 (in Chinses)
9. Ma B, Zhang B (2013) An empirical study on the tournament behavior in the mutual fund industry-fromthe perspective offlow-performance relationship. J Shanxi Financ Econ Univ 30(4):20–29 (in Chinses)
10. Shan L, Peng W (2012) Fund performance ranking and fund managers' risk-taking behavior. Rev Investment Stud 2
11. Sun J, Qiu W (2005) Investigation of fund mangers' risk-taking behavior motivated by fund tournament. J Beijing Univ Aeronaut Astronaut 18(6):5–9 (in Chinses)

Chapter 124
Institutional Investors, Managers' Power and Environmental Performance Information Disclosure: Evidence from Listed Firms of Heavy Polluting Industries in Shanghai Stock Exchange of China

Jing Xu and Liming Zhang

Abstract The level of the firms' environmental performance information is related to managers' private benefit behaviour influenced by power strengths. Meanwhile, institutional investors are able to balance managers' power and impact managers' behaviour decisions. In the context of existing selective disclosure environmental performance information happening to managers, whether are institutional investors able to contribute to weaken or restrain this kind of behaviours and further improve the quality of our listed firms' environmental performance information disclosure? On the basis of the stakeholder theory and manager power theory, this paper chooses heavy-polluted listed firms on Shanghai Stock Exchange between 2008 and 2011 as the objects of research and empirically tests the influence of institutional investors and managers' power on environmental performance information disclosure. The results show that higher managers' power will negatively affect environmental performance information disclosure, but stable institutional investors are able to control managers' power positively and effectively guide them to disclose environmental performance information. While, unstable institutional investors won't do as previous. Furthermore, the environmental performance information disclosure quality of state-owned listed firms is significantly higher than non-state-owned ones.

Keywords Institutional investors · Managers' power · Environmental performance information disclosure

---

J. Xu · L. Zhang (✉)
Business School, Sichuan University, Chengdu 610000, People's Republic of China
e-mail: zhangliming@vip.163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_124

124.1 Introduction

Over the years, Chinese extensive economic development patterns overly rely on the resource. The unbalance problems with environment and economic development are becoming serious. The significant problems, which China has to face are: the fragile ecological environment, insufficient environmental capacity and pollution. All these problems have concentrated emergence. In enterprise culture, environmental performance information is about environment protection and achievement a firm got, which included direct environment results from production and operating activities and environmental awareness [4].

But, we couldn't be optimistic about the environmental information disclosure in China. Many firms publish their situation only in two situations. First, they are pressured from the government. Second, they just want to please the investors. Managers play significant roles in strategic decision-making and implementation, strategic reform, strategic management performance [9]. Among the managers, directors, stockholders and media have some relationship with information disclosure [18]. They have the key positions in competitive advantage [16]. And more, they also have discretionary power and decision-making authority on environmental information disclosure [14]. While, managers could use their power to cover the disclosure of the contents, or the media for their own benefits.

Thus, the firm always filters the information. It has a selective publication. Albertin found the economical situation affected largely on companies' environmental performance and information disclosure [1].

Agency theory deems managers naturally stick to the private benefit of opportunism. Because of the institutional issues, there are lots of alternative activities could be chosen to damage interests in the company in China. In addition, majority of them is for managers' private benefit.

So, is the selective disclosure a "cross-line" decision that managers use their power to cover the private benefit? Is there an effective mechanism to curb these behaviours? We all know the market will react. According to the point, to see from the perspective of the manager's power, this paper studies the motivation and extent of environmental information disclosure that managers has influence on. We try to demonstrate whether the Chinese institutional investors could restrict the managers' power of selective disclosure. So, it will increase the level and quality of information disclosure around listed companies. Additionally, improving the quality of information disclosure could gain the pure value premium on the market.

The rest of article is organized as follows. Section 124.2 discusses the theory and formally develops our hypothesis. Section 124.3 describes our samples and the variables that we employ in our empirical tests. Section 124.4 presents the results and discusses their implications. Section 124.5 concludes the paper and gives suggestions.

124.2 Theoretical Analysis and Hypothesis Construction

Frankly speaking, the environmental performance information should be announced as official by the managers. But their private motivation affects the program. Ness and Mirza [15] thought Corporate social responsibility information disclosure is an indication of the agency problem. Companies should take the responsibility initiatively [12]. According to rational-economic assumption, managers will determine whether to publish the information, content and extent while considering their private benefit [13]. Because of selective activities, managers' power is so important, which decides whether the motivation of private benefit could be true. For this reason, how to make the interests in managers and others as a whole are becoming the key to solve this problem. Many scholars consider CEO duality could enhance the power to the board and thereby influence organizational outcomes [3]. In terms of company information disclosure, Sora [19] has suggested CEO duality would reduce the function of agency cost. It's because that duty of chairman is to lead the board for supervision and decision-making. If he is also the CEO, it means that this one acts as both a player and judge. So, the indicators-the CEO duality and MBO that present the level of managers' power. Both of them strongly affect the selective disclosure activities. Now, we propose the Hypothesis 1 and 2:

Hypothesis 1 (H1): There is a negative correlation between CEO duality and level of environmental information disclosure.

Hypothesis 2 (H2): There is a negative correlation between MBO or not and level of environmental information disclosure.

However, the influence from managers to organizational outcomes is also affected by environmental diversity [10]. When it's in power struggle process, managers' activities got effect from external task environment, internal organizational structure and managers' own characteristics [6]. Majority of researches indicated that institutional investors with share and voting right have influence on corporate decisions. In addition, institutional investors could restrict or constrain the power range of managers. They play a role in information disclosure. For that reason, we propose Hypothesis 3:

Hypothesis 3 (H3): If the share proportion of institutional investors rise, the level of environmental performance information disclosure will be higher, and more restricts and constrains on managers' power.

Actually, it depends on the types of institutional investors as well. Just a part of institutional investors would like to exercise a supervisory role. For those who want to earn profit in the short term, their best choice is becoming an accomplice with internal managers. It's not good for them to raise the extent of information disclosure. Otherwise, they want more unpublished and inside information [20]. For instance, Schadewitz [22] believed short-vision institutional investors would like to lower the extent of information disclosure by forming accomplices with managers. Last but not least, Hartzell and Starks [11] also claimed this kind of institutional investors would sacrifice anything to impact the stock price for extra profit with managers, even the firm's core competence. So, only some institutional investors who hold stock for a long run are prone to supervise the managers' power and their selective disclosure activities. Therefore, we propose Hypothesis 4.

Hypothesis 4 (H4): The stable institutional investors are incentive to supervise managers' power so that increase extent of environmental information disclosure. But the transactional institutional investors will not.

On the other hand, in terms of sustained development on environmental performance, the listed companies have more national investment and policy-aid. At the same time, they have more social responsibility and more supervision from government, public and the media [7]. The attention to media will generate the better interaction [2] and various cognition [21] between customers and corporations. They tend to make the environmental performance information cleared [17]. So, we propose Hypothesis 5.

Hypothesis 5 (H5): State holding listed company has higher extent of environmental performance information disclosure.

124.3 Sample Data and Research Design

124.3.1 Sample and Data Resource

We choose some SSE listed companies in heavy pollution industry as the sample and filter on these conditions.

(1) Eliminate the new listed companies after 2008. (2) Eliminate the ST companies affected by extreme factors. (3) Eliminate the companies that have a change on CEO position. (4) Eliminate the companies that have data deficient. Finally, we get 110 companies and 440 samples. For the record, heavy pollution industry includes 9 types of firms.

124.3.2 Descriptive Variables

(1) Explained Variables

Environmental performance information disclosure index: EDI. Now, Chinese listed companies provide their environmental information voluntarily. There is no standard principle to ask them to provide the information. Because of that, the unconcealed information is published for random or self-interests. It's difficult to value one's performance based on the known information. The environmental information is lack of comparability, amongst companies of the same industry and different industries. So, we construct EDI1 index from the view of disclosure types, and EDI2 index from the view of disclosure content.

① EDI1 index

In fact, lots of published reports on listed companies refer to environmental information. But, because of the principle of voluntary, there is room for firms to select information to publish. For instance, disclosure of environmental information appears in accounting data, abstract of business performance, corporate governance structure, director's report, and financial report, especially the director's report. So, we construct the EDI1 index by using the annual reports, social responsibility report, prospectus and environment report as criterion. After data collection, we give them different scores depends on whether they reveal or not.

② EDI2 index

We combine the related researches by some Chinese scholars [23] and use index method to quantify the extent of environmental performance information disclosure. According to sustainability development reports (third version) on Global Reporting Initiative (GRI), we use valuation indices to score environmental performance information. The formula is constructed as follows

$$\mathrm{EDI2} = \sum_{i=1}^{3} D_i.$$

(2) Explanatory Variable

See Table 124.1.

(3) Control Variable

① Asset scale

An early research by Wang [23] has found the bigger scale the company is, the higher quality of information disclosure has. So, we choose total asset logarithm (LnSIZE) as measurable indicators.

Table 124.1 Definition of explanatory variable

Variable explanation	Abbr.	Definition
CEO duality	CAR	It gets 1 point when there is CEO duality, otherwise, 0 point.
Executive shareholders	SHA	It gets 1 point when the managers hold shares, otherwise, 0 point.
Percentage of institutional investors share-holding	INS	Proportion of institutional investors' share-holding/total equity
Stable investors	STA1	Proportion of institutional investors' share-holding/its standard deviation of share proportion in 3 years
	STA2	If STA2 >= the median of STA1, STA2 take the value of 1, otherwise, 0we regard a institutional investor as stable one if its STA2 gets 1 point.
Equity	EQU	If the controller is government or state-owned enterprise, the variable take the value of 1, otherwise, 0.

② Share-holding concentration rate

Used by data onto listed companies in France, Cormier and Magnan [5] has found the share-holding concentration rate has a positive correlation with quality of information disclosure. So, we choose equity proportions of major shareholders (TOP1) as measurable indicators.

TOP1 = equity proportion of largest shareholder/total equity.

③ Profitability

Froster et al. [24] thought that the companies have strong profitability are prone to pay more attention on environment protection. Thus, they would like to present their environmental performance information, which show their contribution to society. So, we choose return of equity (ROE) as measurable indicators.

ROE = net profit/equity.

124.3.3 Model Construction

As mentioned earlier, we use separate regression model (124.1) and variable interaction regression model (124.2) to testify the related assumptions.

$$\begin{aligned} \mathrm{EDI}_i = {} & \beta_0 + \beta_1 \times \mathrm{CAR} + \beta_2 \times \mathrm{SHA} + \beta_3 \times \mathrm{INS} + \beta_4 \times \mathrm{STA}_i + \beta_5 \times \mathrm{EQU} \\ & + \beta_6 \times \mathrm{InSIZE} + \beta_7 \times \mathrm{TOP1} + \beta_8 \times \mathrm{ROE} + \varepsilon, \end{aligned} \tag{124.1}$$

$$\begin{aligned} \mathrm{EDI}_i = {} & \beta_0 + \beta_1 \times \mathrm{CAR} + \beta_2 \times \mathrm{SHA} + \beta_3 \times \mathrm{INS} \times \mathrm{CAR} + \beta_4 \times \mathrm{INS} \times \mathrm{SHA} \\ & + \beta_5 \times \mathrm{EQU} + \beta_6 \times \mathrm{InSIZE} + \beta_7 \times \mathrm{TOP1} + \beta_8 \times \mathrm{ROE} + \varepsilon, \quad i = 1 \text{ or } 2. \end{aligned} \tag{124.2}$$

124.4 Empirical Results and Discussion

124.4.1 Descriptive Statistic Results and Analysis

From the data we collected, we present the minimum, the maximum, the average and the standard deviation of every index.

As is showed in Table 124.2, the average of EDI1 and EDI2 are 0.55 and 1.83 respectively. In the whole sample, the percentage of companies which have 3 or 3 more reports is 10.9 %, percentage of companies which have 2 reports is 32.7 %, those who only have one report or less accounts for 56.4 %. Besides, the average of EDI2 is 1.83; there is a big gap between the maximum and the minimum. Only 8 % companies have 7 points, which means we can't be optimistic about the environmental performance information disclosure around listed companies, even though the situation is gradually improved. The activities of selective disclosure still exist.

Table 124.2 Variable descriptive statistics

	Min	Max	Average	Standard deviation
CAR	0	1	0.2	0.402
SHA	0	1	0.24	0.427
INS	0	35.68	11.48	8.458
STA1	0	0.024	0.003	0.005
STA2	0	1	0.45	0.5
EQU	0	1	0.54	0.501
LnSIZE	0	28.41	22.005	3.36
TOP1	3.62	86.51	34.356	16.604
ROE	−86.61	394.19	9.945	39.742
EDI1	0	2	0.55	0.686
EDI2	0	7	1.83	1.999

Furthermore, the average percentage of TOP1 is 34.356 %, the maximum is 86.51 %, and the minimum is 3.62 %. The percentage of companies, whose TOP1 is more than 50 %, is 19.09 % in the whole data. From the viewpoint of actual owner, state-owned companies account for 53.6 % in the whole sample. This implies the majority of heavy pollution companies belong to the country. They are on the tendency towards turning into listed firms by reform. Also, we can see the average of INS is 11.48 %. Percentage of companies of institutional investors who hold more than 10 % shares is 50 %. And, the maximum reach to 35.68 %. Given that situation, it indicates institutional investors always hold shares in listed firms and increase their proportion. Meanwhile, we find the average of STA1 is 0.003, and standard deviation is 0.005. The results account for this reason why we classify the types of institutional investors. In STA2, the percentage of samples whose STA2 $= 1$ is 45.45 %. It means more and more institutional investors are becoming stable investors. At last, the percentage of companies that has CEO duality is 20 %. It can be seen that the most firms believe agency theory. CEO duality could limit the supervision and constrain of the board and make the board's decision follow managers' will. In the sample, the number of CEO duality is decreasing that tells the promotion of the management level in China. We also find the average of SHA is 23.6 %, because share-holding concentration rate is high in our country, and most of these equity belonged to the country. The rigid regulation on state-owned stock transition allows a small number of managers have the equity.

124.4.2 Regression Results and Analysis

(1) Regression Results and Analysis Based on the Whole Sample

In the Table 124.3, the CAR and SHA indexes have the significant effect on equality of environmental performance information disclosure. Under the level of 5 and

Table 124.3 Regression results of EDI1 and EDI2 in whole sample

Variables	EDI1	EDI2
Intercept	−1.006*	−1.082
	(−1.705)	(−0.63)
CAR	−0.58**	−0.971***
	(−1.845)	(−1.984)
SHA	0.126	0.769*
	−0.784	−1.678
INS	0.01	0.017
	−1.276	−0.741
EQU	0.434***	0.219***
	−3.156	−2.378
LnSIZE	0.052**	0.09*
	−1.999	−1.588
TOP1	0.002	0.02
	−0.395	−1.509
ROE	−0.004	−0.003
	(−0.248)	(−0.544)
R^2	0.423	0.392
Adjust–R^2	0.383	0.349
F	33.038***	32.255**
Sig.	0.006	0.036

1 %, CAR index shows the negative correlation obviously. That is to say, the results conform to the Hypothesis 1. The results document that CEO duality impacts selective activities on environmental performance disclosure. Selective activities would definitely affect the equality of information, and the disclosure has to rely on the managers' will. However, the SHA index and EDI2 both showed positive correlation between the levels of 10 %. So the *Hypothesis 2* is invalid. It implies that, even though MBO increased from managers' power, at the same time, also relieve agency conflict. The MBO stimulates the combination of interests in managers and corporate's targets. Besides, the managers concerned more about corporate external prestige and the sustained effect of company on social responsibility, which improve their behaviour of selective disclosure on self-interests. Nevertheless, as we can see from the results, regression results of CAR are bigger than that of SHA. It means CAR has bigger effect than SHA on environmental performance information disclosure.

On the other hand, even the INS index has the positive influence on the extent of environmental information disclosure; the regression results are not obvious. Maybe it's the reason that we didn't divide the samples of stable institutional investors or transactional institutional investors according to STA2. Furthermore, there is a positive correlation between EQU and EDI on level of 1 %. It means the Hypothesis 5 is valid. We find that state-owned enterprises assume more social responsibility and spend more thought on the reputation. The social duty and targets they naturally have could guide the managers presenting more environmental information and constrain the activities of selective disclosure. And more, state-owned listed companies is willing to maximize the social benefits. The appointment process from government and rigid regulation of supervision directly affect the decision of the managers.

(2) The Regression Results in Groups and Analysis

Under the condition of institutional investors' groups, the results of Table 124.4 indicate the effect from institutional investors' share-holding proportions and manager's power to the level of environmental performance information disclosure. The results show that when institutional investors are for the transaction (STA2 = 0), INS has a significant negative correlation with EDI on the level of 10 %. When there are more transactional institutional investors, the activities of selective disclosure on environmental information become very normal. For that reason, the transactional institutional investors lower the level of environmental information disclosure. However, when institutional investors are stable (STA2 = 1), INS has a positive correlation separately with EDI1 and EDI2 on the level of 10 and 5 %. The more shares the sta-

Table 124.4 Regression results of EDI1 and EDI2 in whole sample

Variables	STA2 = 1		STA2 = 0	
	EDI1	EDI2	EDI1	EDI2
Intercept	−1.625**	−2.267	−0.584	−3.593
	(−2.271)	(−1.018)	(−0.395)	(−0.844)
CAR	−0.637**	−0.719**	−0.532**	−1.297**
	(−2.269)	(−1.822)	(−2.445)	(−2.073)
SHA	0.031	0.329	0.059	0.691*
	−0.115	−0.391	−0.288	−1.87
INS	0.057*	0.042**	−0.012*	−0.021*
	−1.607	−1.958	−1.795	−1.628
EQU	0.447**	1.021*	0.407**	0.61*
	−2.152	−1.78	−2.213	−1.806
LnSIZE	0.071**	0.117**	0.046	0.254*
	−2.358	−1.899	−0.639	−1.739
TOP1	0.004	0.007	0.001	0.015
	−0.63	−0.339	−0.104	−0.773
ROE	0.001	0.019	−0.001	−0.004
	−0.162	−0.71	(−0.61)	(−0.866)
R^2	0.489	0.488	0.395	0.411
Adjust–R^2	0.365	0.446	0.356	0.393
F	29.32**	31.325***	28.424**	31.791***
Sig.	0.044	0.005	0.033	0.002

Note* ***means it's obvious on level of 1 %, means it's obvious on level of 5 %,* means it's obvious on level of 10 %

ble ones hold, the higher extent of disclosure has. Therefore, the results conform to Hypothesis 4.

Compared to the no significant relationship between INS and EDI in the whole sample, from different types of institutional investors, we can understand the effect from the share-holding of institutional investors on environmental information disclosure. It can also confirm that, because of the transactional institutional investors, INS and EDI are not significant. Transactional institutional investors focus on the trading in short term. Their high proportion of share-holding could negatively impact the environmental performance disclosure. On the contrary, the stable institutional investors purpose to share the profit from enterprising value growth. They concern more about the market response to information disclosure, emotional management of stakeholder and improvement of management. So, the results show the obvious positive consequence.

With further concern, we find ROE has a negative correlation with environmental performance information about the whole sample. But, there is an obvious positive correlation with EDI within the sample group of stable institutional investors. In the sample group of transactional institutional investors, ROE has a negative correlation with EDI. That is to say, the listed companies that stable institutional investors have invested are prone to raise the level of environmental information disclosure when the profits are good. And the companies that transactional ones laid money in would like to cover the content of environmental performance information when the earnings are poor. This phenomenon meets the speculative motive of the transactional institutional investors (Table 124.5).

(3) Interaction Regression Results and Analysis

For further study on whether the influence mechanism of the share-holding of institutional investors and types on environmental performance information disclosure is transmitted by manager's power, we group the samples depend on types of institutional investors. We use EDIs as the dependent variables to run interaction regression models. The results of Table 124.4 show conductive process has a close relationship to managers' power. Firstly, the interaction between the share-holding proportion of stable investors and mangers' power has a positive effect on environmental information disclosure. The interaction of INS*CAR has a significant positive correlation with EDI1 on the level of 5 %. And the negative correlation of CAR and EDI is not obvious. So, it means, on condition of CEO duality, stable institutional investors is helpful to remit the selective activities of disclosure by managers. Secondly, the interaction of INS*SHA is positive correlation with EDI2 on the level of 5 %. It provides the evidence that stable institutional investor is good for information disclosure in the context of MBO. The two above interaction results both demonstrate the stable institutional investors play the active roles in management of environmental performance information disclosure of listed companies. However, interaction between transactional investors and managers' power present the opposite consequence. We also find that, when the $STA2 = 0$, the interaction of INS and CAR has negative correlation with EDI1 on the level of 10 %. It shows the transactional institutional investors have no willing and ability to limit the activities

Table 124.5 Interaction regression results of management power, institutional investor and environmental performance

Variables	STA2 = 1		STA2 = 0	
	EDI1	EDI2	EDI1	EDI2
Intercept	−1.258*	−1.99	−0.733	−3.764
	(−1.818)	(−0.915)	(−0.466)	(−0.834)
CAR	−0.946	−0.28	−0.42	−1.233
	(−1.314)	(−0.124)	(−1.119)	(−1.144)
SHA	0.38*	2.999*	0.014	1.256**
	−1.745	−1.871	−0.039	−1.921
INS	0.01*	0.002**	−0.002	−0.004
	−1.758	−1.858	(−0.127)	(−0.075)
INS*CAR	0.089**	0.028	−0.013*	−0.003
	−2.357	−0.233	(−1.893)	(−0.034)
INS*SHA	0.029	0.209**	−0.007	−0.05**
	−1.045	−2.39	(−0.266)	(−2.182)
EQU	0.313	1.196*	0.395**	−0.576
	−1.506	−1.833	−2.013	(−1.022)
LnSIZE	0.068**	0.133	0.053	0.25
	−2.391	−1.491	−0.712	−1.172
TOP1	0.002	−0.005	0.02	0.016
	−0.324	(−0.237)	−0.056	−0.828
ROE	0.006	0.044	−0.001	−0.004
	−0.631	−1.562	(−0.597)	(−0.837)
R^2	0.395	0.295	0.27	0.239
Adjust–R^2	0.251	0.218	0.25	0.214
F	29.753**	21.768**	28.54*	23.404**
Sig.	0.014	0.034	0.084	0.021

Note* ***means it's obvious on level of 1 %, means it's obvious on level of 5 %,* means it's obvious on level of 10 %

of managers' selective disclosure when there exists CEO duality. The transactional institutional investors who are willing to gain the profit in the short term would like to tolerate the managers' opportunism. Moreover, the interaction of INS and SHA is obvious negative correlation with EDI2 on the level of 5 %. The results are opposite to the interaction regression results of stable institutional investors. Surprisingly, the MBO has the negative effect after being invested by the transactional investors. Because we already know the MBO can remit the agency problem. The appearance of transactional institutional investors and MBO could encourage the activities of selective disclosure of environmental information disclosure.

The regression results from all above documenting the importance of institutional investors. Only the stable institutional investors would like to raise the disclosure level of environmental performance information by limiting the managers' power.

But the transactional investors wouldn't care about the development in the long run. They would not increase the transparency of environmental information by the positive management. Frankly speaking, they won't interfere the activities of selective disclosure.

124.5 Conclusions

The results indicate only the interaction between stable institutional investors' share proportions and managers' power have the heavy effect on the indexes of information disclosure of environmental performance. Thus, there are two methods to restrict the managers' selective activities about environmental performance information disclosure. In addition, methods also can increase the equality of this information.

(1) Strengthen supervision to managers. In order to avoid the damage to extreme decision, we should restrict the managers' power reasonably. In China, most of these listed companies are state-owned. The unclear ownership and the "pyramid" controlled structure support managers with decision power that government can hardly monitor. Only in this way, the environmental responsibility and the level of environmental performance information disclosure of Chinese firm could be raised.

(2) The corporates need to attract and develop more stable institutional investors. According to the results, stable investors are capable and willing to influence environmental performance information disclosure, which can improve their long-term performance and help them to make right decisions. Furthermore, invested in a similar but a better performance company, investors could get the same payment on smaller risk [8]. Thus, the institutional investors are more likely to invest in the companies with better social performance. Honestly, the market will accept them more. We suggest developing stable institutional investors.

References

1. Albertini E (2014) A descriptive analysis of environmental disclosure: a longitudinal study of french companies. J Bus Ethics 121(2):233–254
2. Bae H (2014) Voluntary disclosure of environmental performance: Do publicly and privately owned organizations face different incentives/disincentives? Am Rev Public Adm 44(4):459–476
3. Chung KH, Wright P, Kedia B (2003) Corporate governance and market valuation of capital and R&D investments. Rev Financ Econ 12(2):161–172
4. Corbett CJ, Pan J (2003) Evaluating environmental performance using statistical process control techniques. Qual Control Appl Stat 48(1):37–40
5. Cormier D, Magnan M (2003) Environmental reporting management: a continental european perspective. J Account Public Policy 22(1):43–62
6. Finkelstein S, Boyd BK (1998) How much does the ceo matter? the role of managerial discretion in the setting of ceo compensation. Acad Manag J 41(2):179–199

7. Gongrong C, Ning M, Qishan L (2011) The empirical study on the correlation of the quality of environmental information disclosure and corporate governance. Acad Forum 9:150–155 (in Chinese)
8. Graves SB, Waddock SA (1994) Institutional owners and corporate social performance. Acad Manag J 37(4):1034–1046
9. Guopeng X (2004) The strategic management role of middle manager and inspiration from the view of western scholars. Foreign Econ Manag 26(5):21–25 (in Chinese)
10. Hambrick D, Finkelstein S (1987) Managerial discretion:a bridge between polar views of organizations. Res Organ Behav 9:369–406
11. Hartzell J, Starks L (2003) Institutional investors and executive compensaitons. J Financ 58(6):2351–2374
12. He C, Loftus J (2014) Does environmental reporting reflect environmental performance?: Evidence from China. Pac Account Rev 26:134–154
13. Hong J, Zhang X, Su C (2011) Changes in performance of listed companies and analyst predictable behavior. In: Conference prceeding of accounting society of China. Springer, pp 815–831
14. Huang J, Zhou C (2012) The empirical study of the effect from managers' activity on environmental information disclosure-based on the experience and evidence of listed companies of sse in heavy pollution industry. China Soft Sci Mag 1:95–106
15. Ke N, Mirza AM (1991) Corporate social disclosure: a note on a test of agency theory. Br Account Rev 23(3):211–217
16. King AW, Zeithaml CP (2001) Managing organizational competencies for competitive advantage: the middle-management edge. Acad Manag Exec 15(2):95–106 (in Chinese)
17. Li Z (2006) The correlation of corporate responsibility and corporate value. China Ind Econ 2:77–83 (in Chinese)
18. Miller GS, Skinner DJ (2015) The evolving disclosure landscape: How changes in technology, the media, and capital markets are affecting disclosure. J Account Res 53(2):221–239
19. Natale SM (2004) The ethical dilemma of merging the roles of ceo and chairman of the board. Corp Gov Int J Bus Soc 4(2):64–68
20. Niu J, Wu C, Li S (2013) The types of institutional investors, characteristics of equity and voluntary information disclosure. Manag Rev 3:48–59 (in Chinese)
21. Nyilasy G, Gangadharbatla H, Paladino A (2014) Perceived greenwashing: the interactive effects of green advertising and corporate environmental performance on consumer reactions. J Bus Ethics 125(4):693–707
22. Schadewitz HJ, Blevins DR (1999) Major determinants of interim disclosures in an emerging market. Am Bus Rev 16:41–55
23. Wang J (2008) The study on the correlation of environmental information disclosure, industry differences and external institutional pressure-based on the environmental information evidence of listed companies in sse. Account Res 6:54–62 (in Chinese)
24. Wilmshurst TD (2000) Corporate environmental reporting: a test of legitimacy theory. Account Audit Account J 13(1):10–26

Chapter 125
Financial Performance Early-Warning of Drilling

Yue He, Can Zhu, Jing Yin and Hongming Zhu

Abstract This thesis establishes a drilling financial performance evaluation system, which is suitable for drilling companies under the guidance of the performance theory and it does the drilling performance early-warning using the single index and synthesized index method of economic early-warning theory. In the end, this thesis does an empirical study of drilling company A. The method of drilling performance early-warning this thesis proposes realizes the monitoring of drilling performance, and timely early-warning in the event of an exception. So the drilling company can take the timely and effective measures to ensure the benefits of drilling.

Keywords Rilling engineering · Financial performance · Economic early-warning · Factor analysis

125.1 Introduction

Currently the researches on the investigations and appraisals of wells have been very mature, but there is no scientific control about performance and loss of single-well in the process of drilling the well. Therefore it is needed to establish a drilling financial performance evaluation system, which can evaluate the financial status in the drilling process scientifically, so that users can find the potential dangers and take effective measures in time.

In regard to performance, there are three kinds of definition abroad: performance is the results [2], performance is the behaviors [5], and performance is a combination of behaviors and results [4]. In our country most experts approve the last one, believing that performance is the results and performance is the behaviors as well. Neither is dispensable [9]. In addition, there are many theories on performance in China. Zhang [21] proposed to use systematic thoughts to manage performance. Zheng and

Y. He · C. Zhu (✉) · J. Yin · H. Zhu
Business School, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: cathleen3359@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_125

Luo [23] proposed the performance evaluation mechanism which applied the agent performance. Sun and Zhang [17] proposed a multidimensional dynamic assessment.

For early-warning, most study abroad focused on military use, later covering economy, agriculture, environment, energy and so on. Economic early-warning, which is the most widely used, has many research results. Stelaer [16] used colors to reflect the economic fluctuations. Brooke Dahl Institute for Economic Research set up a comprehensive stock index of many aspects of the economy. Parsons prepared the "economic barometer" and "American General Business Index" [6]. Domestic research started later but got rapid developments, ranging from economic early-warning [14] to environmental early-warning [1, 24] to energy early-warning [8] to agricultural early-warning [18]. The researches about economic early-warning have been mature relatively.

For drilling performance, comprehensive performance has been concerned at home and abroad, while there are less studies about the performance of drilling process. Even the early-warning researches about drilling financial performance can not be inquired. This thesis proposes the drilling financial performance early-warning and combines financial performance with economic early-warning. Firstly the theories of performance have been used synthetically to ensure indicators of drilling financial performance early-warning. Then it combines early-warning with drilling financial performance, which uses some theories of economic early-warning. So that the financial performance early-warning of drilling has been realized.

125.2 The Establishments of a Drilling Financial Performance Evaluation System

125.2.1 The Performance Theories

There are many methods of performance evaluation. Key Performance Indicator, Careersmart Balanced Score Card and 360-degree Behaviorally Anchored Rating Scale have been commonly used [19]. Careersmart Balanced Score Card [15] focused more on the relationship between performance management and corporate strategies while 360-degree Behaviorally Anchored Rating Scale focused more on working behaviors. Neither is suitable for the present study. For the reason that this thesis selects Key Performance Indicator to establish a drilling financial performance evaluation system.

Key Performance Indicator, which is in combination with Management by Objectives and Pareto Principle, has the basic idea that organizational goals have been decomposed comprehensively firstly, then the decisive factors which influenced goals have been analyzed and generalized. In the end, the key indicators of performance have been refined [20].

According to the process of refining the key indicators, some important principles which can be abbreviated to SMART should be followed when using this method

[7]. S means Specific, referring the performance indexes should be specific, rather than probable. M means Measurable, indicating that the performance indexes should be measurable and some data of performance indexes can be available. A means Attainable, referring the goals about performance indexes can be attainable. And then R means Relevant, indicating that the performance indexes should have an influence on the goals and should not depart from the organization's goals as well. Finally T means Time bound, referring performance indexes should be time-limited.

125.2.2 The Indexes of a Drilling Financial Performance Evaluation System

According to the principles above mentioned, 20 indexes of reflecting the drilling financial performance have been obtained by communicating deeply with experts and organizing large amounts of data in order to achieve a comprehensive evaluation of the financial performance of drilling. The results are shown in Table 125.1.

It is not hard to see some indexes of a drilling financial performance evaluation system above are redundant from Table 125.1. It needs further selection to build a new drilling financial performance evaluation system more suitable for early-warning.

First of all, qualitative analysis should be operated primarily. Considering the drilling condition of companies and the existing data, not all data of the indexes have the value monthly and it does not correspond with Measurable principles. So these indexes should be ruled out. And some indexes absolute value and the proportion of the value are too small to influence performance goals. It does not correspond with Relevant principles so that they should be ruled out too. The new results can be seen in Table 125.2.

Table 125.1 The indexes of a drilling financial performance evaluation system

① Drill	② Drilling fluid	③ Diesel fuel	④ Engine oil
⑤ Other materials	⑥ Transportation fee	⑦ Drilling costs of special tools	⑧ Installation of water and subsequent management fee
⑨ Labor costs	⑩ Utility bills	⑪ Communication fee	⑫ Equipment daily maintenance fee
⑬ Environmental protection fee	⑭ Other direct costs	⑮ HSE fee (Heath Safety Environment fee)	⑯ Original test oil rig construction costs
⑰ Tool joints, screw, stabilizer, shock absorber and jar use fee	⑱ Well control device subsequent management fee	⑲ Rig removal and installation expenses	⑳ Drilling tool lifting fee

Table 125.2 The proportion of the value of every index

Number	Drilling financial indexes	Proportion	Results	Number	Drilling financial indexes	Proportion	Results
1	Drill	>1 %	Selected	11	Communication fee	<1 %	Excluded
2	Drilling fluid	>1 %	Selected	12	Equipment daily maintenance fee	>1 %	Selected
3	Diesel fuel	>1 %	Selected	13	Environmental protection fee	>1 %	Selected
4	Engine oil	>1 %	Selected	14	Other direct costs	>1 %	Selected
5	Other materials	>1 %	Selected	15	HSE fee(Heath Safety Environment fee)	<1 %	Excluded
6	Transportation fee	>1 %	Selected	16	Original test oil rig construction costs	<1 %	Excluded
7	Drilling costs of special tools	>1 %	Selected	17	Tool joints, screw, Stabilizer, shock absorber and jar use fee	<1 %	Excluded
8	Installation of water and subsequent management fee	<1 %	Excluded	18	Well control device subsequent management fee	<1 %	Excluded
9	Labor costs	>1 %	Selected	19	Rig removal and installation expenses	<1 %	Excluded
10	Utility bills	>1 %	Selected	20	Drilling tool lifting fee	<1 %	Excluded

Table 125.3 The results of KMO Measure and Bartlett test of sphericity

KMO measure		0.815
Bartlett test of shpericity	Approx. Chi-Square	32.651
	df	6
	Sig.	0

Table 125.4 The table of total variance decomposition

Number	Initial eigenvalues			The sum of load square		
	Total	Proportion (%)	Cumulative proportion (%)	Total	Proportion (%)	Cumulative proportion (%)
1	11.894	79.294	79.294	11.894	79.294	79.294
2	1.122	7.479	86.773	1.122	7.479	86.773
3	0.827	5.512	92.285	0.827	5.512	92.285
4	0.683	4.555	96.841	0.683	4.555	96.841
5	0.311	2.074	98.915	0.311	2.074	98.915
6	0.081	0.537	99.453	-	-	-
7	0.037	0.249	99.701	-	-	-
8	0.025	0.169	99.87	-	-	-
9	0.013	0.084	99.954	-	-	-
10	0.005	0.035	99.989	-	-	-
11	0.002	0.011	100	-	-	-

At the result of qualitative analysis, there are still a lot of relevance among these indexes, so factor analysis is adopted to reduce the dimension. On the basis of principles of factor analysis [11], 12 indexes are analyzed by SPSS. The results are shown in Tables 125.3 and 125.4.

The results presents that the value of KMO is 0.815, close to 1, so factor analysis is suitable for these indexes. The significance probability of x is 0.000, less than 1 % at the same time, which means there are relevance between these data. So it is feasible to do factor analysis.

According to the results above, 5 indexes are selected to describe drilling financial performance. They are Drill, Drilling fluid, Diesel fuel, Engine oil and Other materials. These factors' characteristic roots can explain 98.915 % of the population variance. So these indexes can reflect the condition of the drilling financial performance.

125.3 The Method Design of Drilling Financial Performance Early-Warning

125.3.1 The Early-Warning Theories

The early-warning theories have a wide range of research and application at home and abroad. According to the characteristics of drilling performance, the thesis refers the single index and synthesized index method of early-warning theory applying to the drilling performance early-warning. The four steps of economic early-warning should be followed at the beginning. First, the early-warning indexes should be ensured. Second, the early-warning method should be selected. Third, the early-warning limits should be determined and finally, the early-warning judgment is important [3].

The single index of early-warning sets a signal of the single index firstly and then the early-warning limits are ensured. Finally the single index of early-warning can be achieved. The early-warning areas are divided into "Superheating", "Partial heat", "Normal", "Cool" and "Supercooling" these five regions, which are represented by "Red", "Yellow", "Green", "Light Blue" and "Blue" these five colors. There are three main ways to determine the limits of the single index: empirical analysis, statistical method, sample specific gravity method [12, 13]. The synthesized index method of early-warning is a process of the whole operation of the early-warning target based on the single index of early-warning. The synthesized index of early-warning selects a set of indexes that are high sensitive and comprehensive and can reflect the actual condition of the early-warning objects as well. At first, the data processing methods are applied to combine many indexes into a comprehensive index. Then the early-warning limits can be determined according to the single index of early-warning. Finally signal lights are used to show the condition of these indexes to realize early-warning [10].

125.3.2 The Analysis of the Single Index of Early-Warning of Drilling Financial Performance

The thesis uses the actual data of the single well A2 from the company A to analyze the single index of early-warning and the synthesized index of early-warning. Some information can be seen in Table 125.5.

(1) The setting of the early-warning signal of the single index

Based on the set mode of the economic early-warning signal, the division of the judging regions and the setting of the signal are carried out, according to the characteristics of the financial performance of drilling in the oil industry.

The early-warning of drilling financial performance is divided into "Too high", "High", "Normal", "Low" and "Too low" these five regions, which are represented

Table 125.5 The information of the single well A2

Name	District	Structure	Rig type	Indexes	The value of index			
					June 2010	July 2020	August 2010	September 2010
A2	B	C	ZJX XX	Drill	12.3	10.1	13.7	0.65
				Drilling fluid	43.53	46.5	4.91	8.91
				Diesel fuel	62.51	52.56	42.2	49.82
				Engine oil	0.4	1.22	0.1	2.95
				Other materials	4.31	6.22	6.24	6.53

by “Red”, “Yellow”, “Green”, “Light Blue” and “Blue” these five colors of lights. “Red light” means the costs are too high that measures should be taken to control. “Yellow light” means the costs are high and they may be stable or higher in the short term. “Green light” means the costs are normal. “Light blue light” means the costs are low, which can be stable or lower in the short term. “Blue light” means the costs are too low, the reasons should be investigated and some measures should be taken in time.

(2) The determination of the early-warning limits of the single index

Part of the data of the drill in the early-warning indexes of drilling financial performance is shown in Fig. 125.1.

It is not hard to see that the drill data is basically in a regional scale. Whether it is too high or too low, there is a potential danger, so the normal (green light) region should be determined by the upper and lower limits. In addition, in order to avoid the quantitative analysis results divorced from the practice, it is necessary to combine

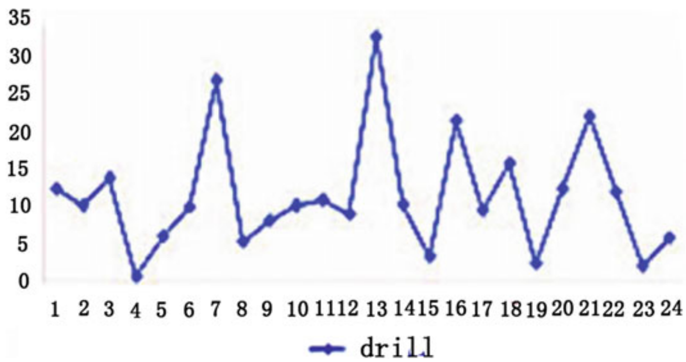


Fig. 125.1 The drill data distribution of the indexes of the drilling performance early-warning

Table 125.6 The critical value of the early-warning indexes in financial performance based on statistical

Name of indexes	Too high	High	Normal	Low	Too low
Drill	≥29.59	29.59 – 25.00	25.00 – 9.73	9.73-5.15	≤5.15
Drilling fluid	≥95.14	95.14 – 79.38	79.38 – 26.86	26.86 – 11.10	≤11.10
Diesel fuel	≥157.74	157.74 – 133.93	133.93 – 54.54	54.54 – 30.73	≤30.73
Engine oil	≥11.19	11.19 – 9.34	9.34 – 3.15	3.15 – 1.30	≤1.30
Other materials	≥42.02	42.02 – 35.19	35.19 – 12.40	12.40 – 5.56	≤5.56

the qualitative analysis to obtain the early-warning limits of the performance index, accorded with drilling characteristics [12, 13]. Based on the above considerations, the empirical analysis, statistical method and sample specific gravity method are selected to ensure the early-warning limits of the single index.

First, the statistical method is used to determine the early-warning limit of the single index. The green light region is determined by the upper and lower limits at the same time, so the green light region accounted for 50 % of the total area, blue light and yellow light accounted for 15 %, the red and blue light accounted for 10 %. Therefor the confidence level is 50 % to determine the upper and lower limit of the green light. And the confidence level is 20 % when determining the values of the boundaries of blue light and yellow light. Thus, the early-warning limits are $-0.68S$, $\bar{X} - 0.25S$, $\bar{X} + 0.25S$, $\bar{X} + 0.68S$, where X is the means of each index and S is standard deviation. The early-warning limits of the single index using MATLAB programming are shown in Table 125.6.

Then the sample specific gravity method is used to ensure the early-warning limit of the single index. Considering the characteristics of drilling, the number of samples of the red light district and blue light district accounted for 10 % of the total respectively, yellow light district and blue light district accounted for 15 % respectively, And green light district accounted for 50 %. The four critical lines of the five light districts are identified, as shown in Table 125.7.

From the results of statistical methods and sample specific gravity method, there is a large gap between the drilling fluid, diesel oil, oil and other materials. So the results

Table 125.7 The critical value of the early-warning indexes in financial performance based on sample specific gravity method

Name of indexes	Too high	High	Normal	Low	Too low
Drill	≥29.12	29.12 – 25.68	25.68 – 8.20	8.20 – 5.20	≤5.20
Drilling fluid	≥67.40	67.40 – 43.50	43.50 – 8.95	8.95 – 1.78	≤1.78
Diesel fuel	≥99.74	99.74 – 65.99	65.99 – 51.53	51.53 – 32.44	≤32.44
Engine oil	≥5.22	5.22 – 3.54	3.54 – 1.02	1.02 – 0.43	≤0.43
Other materials	≥18.92	18.92 – 14.50	14.50 – 4.82	4.82 – 1.97	≤1.97

Table 125.8 The critical value of the early-warning indexes in financial performance based on synthesized method

Name of indexes	Too high	High	Normal	Low	Too low
Drill	≥29.36	29.36 – 25.34	25.34 – 8.97	8.97 – 5.12	≤5.12
Drilling fluid	≥67.40	67.40 – 43.50	43.50 – 8.95	8.95 – 1.78	≤1.78
Diesel fuel	≥99.74	99.74 – 65.99	65.99 – 51.53	51.53 – 32.44	≤32.44
Engine oil	≥5.22	5.22 – 3.54	3.54 – 1.02	1.02 – 0.43	≤0.43
Other materials	≥18.92	18.92 – 14.50	14.50 – 4.82	4.82 – 1.97	≤1.97

of two methods are integrated in this thesis. Combined with the actual situation of drilling and historical experience, the critical value is adjusted and the results are shown in Table 125.8.

125.3.3 The Analysis of the Synthesized Index of Early-Warning of Drilling Financial Performance

(1) The selection of synthesized index of early-warning

Based on the selection principle of the synthesized index of early-warning, the 5 indexes of the financial performance index system of drilling, Drill, Drilling fluid, Diesel oil, Engine oil and other materials are selected as the basis for the selection of indexes.

(2) The calculation of the synthesized score

Because of the different effects of different indexes on the drilling, the weight of the index is given to calculate the synthesized score [22].

$$B = \sum_{i=1}^{M} w_i K_i \tag{125.1}$$

B indicates the comprehensive performance score, W_i represents the weight of the index of i. The final weight is determined by the information entropy method in this thesis, and the status score of i is expressed by K_i.

According to the actual data of the single well A2, using the information entropy method to determine the weights of the synthesized index of early-warning, the calculation results are shown in Table 125.9.

By combining the actual state of the indexes with the weights of the synthesized index of early-warning, the comprehensive index score can be calculated, as shown in Table 125.10.

Table 125.9 The weights of the synthesized index of early-warning

Performance indexes		Information entropy (weights)
Financial performance indexes	Drill	0.206151
	Drilling fluid	0.157391
	Diesel oil	0.415812
	Engine oil	0.080213
	other materials	0.140433

Table 125.10 The comprehensive early-warning score of drilling financial performance

Name	Performance indexes	The value of index			
		June 2010	July 2010	August 2010	September 2010
A2	The comprehensive early-warning score of financial performance	16	15	11	10

Table 125.11 The limits of the synthesized index of early-warning of financial performance

Performance indexes	Red light	Yellow light	Green light	Light blue light	Blue light
	Too high cost	High cost	Normal cost	Low cost	Too low cost
The limits of the synthesized index of early-warning of financial performance	≥21	[21, 18)	[18, 12.5]	(12.5, 9.5]	≤9.5

(3) The determination of the synthesized early-warning limits

Using traditional methods, combined with the drilling of the actual situation, and drilling expert in-depth interviews, it is determined that the 84, 72, 50 and 38 % of the full score 5p (p is the number of the synthesized index of warning) are respectively as the critical value of the "Red light", "Yellow light", "Green light", "Light blue light" and "Blue light". Therefore a synthesized early-warning limit is obtained, as shown in Table 125.11. Of course, the early-warning limit is not static and it should be adjusted according to the situation to get more accurate forecasting results.

Table 125.12 The early-warning signals of drilling financial performance

Name of indexes	In 2010			
	June	July	August	September
1.Drill	🟢	🟢	🟢	⚫
2.Drilling fluid	🟢	🟡	🔵	🔵
3.Diesel fuel	🟢	🟢	🔵	🔵
4.Engine oil	🔵	🟢	⚫	🟢
5.Other materials	🔵	🟢	🟢	🟢
The comprehensive early-warning of financial performance	🟢 16	🟢 15	🔵 11	🔵 10
🔴 Too high	🟡 High	🟢 Normal	🔵 Low	⚫ Too low

125.4 The Analysis of the Early-Warning Results

According to the critical values of each single index, the early-warning signals of the single indexes are obtained. And according to the comprehensive early-warning score of financial performance and the limits of the synthesized index of early-warning, the comprehensive early-warning signals are obtained. Combined with two kinds of early-warning signals, the early-warning signals of drilling financial performance is obtained, as shown in Table 125.12.

From Table 125.12, it can be seen that most of the indexes of financial performance are in the normal state, but the overall change is not coordinated, which is not in a consistent state. Especially the monthly value of the drill is normal in the first three months, but in the fourth months the value is into the low state, which should be closely concerned. The results of the comprehensive early-warning of financial performance shows that the financial performance of the well A2 is good and in a normal state in June and July, but in August and September it is in the state of low cost. One possibility is that the well implemented state is normal and the cost control is proper, so the results are very good. Another possibility is that implementation of the well is in a poor state, leading to the lower costs. And the situation that the required works do not finish may appear. At that time, the reasons should be checked such as completion of the workload. Problems should be found and effective measures should be taken as soon as possible, dealing with issues before they happen.

125.5 Conclusions

First, according to the actual characteristics of the drilling, the performance method is used to establish the drilling financial performance evaluation system. And then on the basis of this, the method of economic early-warning is used to forecast the financial performance of drilling. In the end, this thesis does an empirical study of drilling company A and the financial performance early-warning of drilling has been realized.

The thesis focuses on the performance of the drilling process, and puts forward a set of financial performance evaluation index system, and based on the theories of economic early-warning, the thesis puts forward the concepts, functions and operation processes of the financial performance of drilling. The financial performance monitoring and early-warning of drilling has been realized, which is innovative.

Although the thesis has completed the selection of the early-warning indexes of the financial performance of the drilling, but due to the limitations of knowledge, data and experience, it is still not comprehensive and accurate. Further researches are needed. And in the future more methods will be used to try to improve the accuracy of the drilling financial performance early-warning.

References

1. Beck Bruce M (1991) Forecasting environmental change. J Forecast 3:3–19
2. Bernardin H, Kane J (1993) Performance appraisal: a contingency approach to system development and evaluation. PWS-Kent, Boston
3. Bi D (1990) Economic cycle and early warning system. Science Press, Beijing
4. Brumhrach GB (1988) Performance managements, vol 15. The Cronwell Press, Wiltshire
5. Campbell JP, McCloy RA et al (1993) A theory of performance. In: Personnel selection in organizations, vol. 3570
6. Chu N (2005) Economic crisis and the study of early-warning index system. Ph.D. thesis, East China Normal University, Shanghai (in Chinese)
7. Ding L (2004) KPI, key performance guidelines for success, vol 15. Peking University Presss, Beijing
8. Li J (2007) Study on Chinese energy early warning model. Ph.D. thesis, China University of Petroleum, Beijing (in Chinese)
9. Lifeng Z, Kan S (2002) Several basic issues of performance management. Nankai Bus Rev 3:15–19
10. Liu X (2008) Research on performance evaluation and early-warning of port logistics based on sustainable development. Ph.D. thesis, Tianjin University, Tianjin (in Chinese)
11. Ma Q (2002) Management statistics-data acquisition, statistical principle SPSS tools and applications. Science Press, Beijing
12. Madala RH, Ivakhnenko GA (1994) Inductive learning algorithms for complex systems modeling. CRC Press, Boca Raton
13. Mueller, J-A, Lemke F (2000) Self-organising data mining: extracting knowledge from data
14. Ren W, Huang L (2008) Research on the method of determining the weight of the development level of R&D industry. Sci Technol Manag 2:72–748 (in Chinese)
15. Song P (2008) Research on the method of balanced score card for a company. Ph.D. thesis, Southwestern University of Finance and Economics, Chengdu (In Chinese)
16. Stekler Herman (1994) Are economic forecasts valuable? J Forecast 13(6):495–505
17. Sun Q, Zhang S (2000) Multidimensional dynamic evaluation. Hum Resource Dev China 24(2):8 (In Chinese)
18. Tao J, Chen K, Yangh Y (1994) Introduction to agricultural warning. Kasetsart University Presss, Beijing
19. Yang J (2004) The design of performance management for H3C company. Ph.D. thesis, Shandong University, Jinan (In Chinese)

20. Zhang X (2007) Sz architectural design institute of improvement of performance appraisal systeml. Ph.D. thesis, Northwest University, Xi'an (In Chinese)
21. Zhang D (2001) Human performance technology and its application in business. Chin J Manag Sci 20(2):4–6 (In Chinese)
22. Zhang S (2010) The science and technology evaluation model based on entropy weight and empirical research during the 10th five-year of China. Chin J Manag 1:6 (In Chinese)
23. Zheng S, Luo P (1998) Share cropping & relative performance evaluation mechanism and its efficiency. J Manag Sci 13(1):10–12 (in Chinese)
24. Zimmerer KS (1994) Human geography and the "new ecology": the prospect and promise of integration. Ann Assoc Am Geogr 84(1):108–125

Chapter 126
Adverse Selection Incentive Model and Contract Analysis

Hong Cheng, Hongmei Guo and Xianyu Wang

Abstract Adverse selection can decrease supply chain efficiency and the incentive theory is usually used to combat the inefficiency. To clarify if this inefficiency is influenced by trade credit causing risk to suppliers, incentive models are built separately using Principle-agent theory for trade credit and cash trades. Through solving these models and comparing incentive contracts, this paper arrives at some definitive conclusions. Firstly, incentive contracts can stimulate the supplier to publish the true costs. Secondly, trading quantities under asymmetric information are distorted downwards compared with trading quantities under symmetric information. Thirdly, supply chain efficiency is not influenced by trade credit. The conclusions obtained under the symmetric and asymmetric information conditions and some key model parameters used in this paper are analyzed using a numerical approach.

Keywords Supply chain · Trade credit · Adverse selection · Principle-agent theory · Incentive model

126.1 Introduction

As one of the ways to finance supply chains, trade credit solves retailer capital shortage problems and transfers the unsalable risk from the retailer to the supplier. Therefore, trade credit is widely used and has been the subject of significant research in the logistics field. However, to date, there has been little research that has considered asymmetric information even though it is known that such information can reduce supply chain efficiency. Supply chain management is the integrated management of logistics, information flow and cash flow, so effective coordination of these

---

H. Cheng
College of Management Science, Chengdu University of Technology, Chengdu 610059, People's Republic of China

H. Guo (✉) · X. Wang
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: gsglxy12@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_126

elements can guarantee the highest efficiency of supply chain. Therefore, studying the effect of asymmetric information and trade credit is valuable.

After Goyal [4] introduced the EOQ model to trade credit, research has studied retailer order policies [1, 11] and supplier trade credit policies [7, 10] under different situations. Considering that supply chain efficiency can be reduced by adverse selections caused by asymmetric information. He and Xu [5] found that retailer's capital costs were asymmetric information and built an incentive model to study supplier optimal credit periods and retailer optimal order quantities, which enhanced supply chain efficiency. Yu and Luo [8] used reverse auctions to solve the adverse selection because of supplier's private information about product costs from the retailer perspective. These papers all assumed certain market demand in which the retailer has no unsalable risks. However the market demand was uncertain usually. And this uncertainty make the retailer have unsalable risks and the use of trade credits transfers this risk to the supplier.

Based on this hypothesis of uncertain market demand, Zhang and Luo [9] focused on private information regarding supplier's capital costs and retailer's capital costs, and built a bilateral auction model using auction theory. Cheng [3] focused on a situation in which the retailer's private information was sales abilities and built a principal-agent model to reveal the real costs, which ultimately enhanced supply chain efficiency. However, these studies dealt with the trade credit as being paid twice and ignored the credit risks.

With this background, this article examines retailer's credit risk in relation to uncertain market demand and adverse selections because of supplier's private information about his true costs, and an incentive model is built to reveal the real supplier's costs. Optimal incentive contracts are determined by solving the model and then compared with cash transaction contracts and symmetric information to analyze the differences and the mutual influences of adverse selections and trade credit. The results of this study support trade credit management theory and applications.

126.2 Assumptions and Notations

Consider a tightly coupled supply chain consisting of a supplier and a retailer. The supplier unit cost is c, and the transfer payment is t when the retailer order quantity is Q. The market price is p and market demand per sales period y is a random number with a distribution function $F(y)$ and a density function fy.

The retailer personal cash holdings η are insufficient for the transfer payment t (i.e., $\eta < t$), so, trade credit is used. The retailer pays η on product receipt and a credit payment $(t - \eta)$ is paid from the retailer sales revenue pQ at the end of the sales period. At the end of the sales season, the retailer pays the balance if enough income has been received (i.e., $pQ > t - \eta$). All income is given to the supplier if the retailer receives only a small return on sales (i.e., $pQ < t - \eta$). At this point, the retailer declares bankruptcy, and the supplier is unable to receive the remaining balance.

The unit manufacturing cost c is private information of suppler. The retailer only knows that c is a random number in the range $\left[\underline{c}, \bar{c}\right]$, and the distribution function $G(c)$ and density function $g(c)$. $\frac{G(c)}{g(c)}$ increases as c increases. This assumption is satisfied in most random distribution situations [2].

This paper focuses on perishable goods; therefore, beyond the sales period, the product salvage value is zero. The retailer is unable to reorder during the sales period.

126.3 Modelling

126.3.1 Incentive Model Under Trade Credit and Adverse Selection

Based on the assumption of limited liability, the expected profit for the suppliers and retailers, respectively, are as follows:

$$\pi_s = t - cQ - \int_0^{y_0} pF(y)\,dy, \tag{126.1}$$

$$\pi_r = \int^{\bar{c}} \left(pQ - t - \int_{y_0}^{Q} pF(y)\,dy \right) g(c)\,dc, \tag{126.2}$$

in which $y_0 = \frac{t-\eta}{p}$.

In this supply chain, the retailer is in the position of stimulation, and the supplier is in a weaker position and can only be stimulated; for example, as in the relationship between a hypermarket and a small supplier. This is the principal-agent relationship. Figure 126.1 shows the timing of contracting between the supplier and the retailer. At first, the supplier is informed of his manufacturing cost $c \in [, \bar{c}]$, which is considered private information. Then, the retailer provides an incentive contract menu $\{(t(c), Q(c))\}$. The supplier chooses a contract from the menu or withdraws from the sale. If the supplier chooses a contract, the contract is executed when the sales are realized. The timing of the contracting game under adverse selection can be summarized as follows:

In Fig. 126.1, S represents the supplier and R represents the retailer.

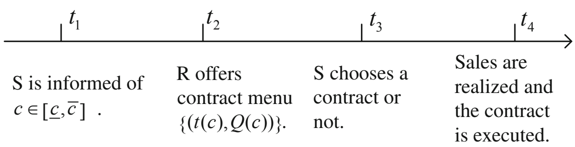


Fig. 126.1 Timing of contracting under adverse selection

Based on the revelation principle, from the perspective of the retailer, the incentive model is built as follows:

$$P1: \max_{\{(t(c),Q(c))\}} \pi_r = \int^{\bar{c}} \left(pQ - t - \int_{y_0}^{Q} pF(y)\,dy \right) g(c)\,dc, \tag{126.3}$$

$$s.t.\ \pi_s(c,c) = t - cQ - \int_0^{y_0} pF(y)\,dy \geq 0, \tag{126.4}$$

$$\pi_s\left(c,\hat{c}\right) = t\left(\hat{c}\right) - cQ\left(\hat{c}\right) - \int_0^{y_0} pF(y)\,dy, \tag{126.5}$$

$$\pi_s(c,c) \geq \pi_s\left(c,\hat{c}\right), \tag{126.6}$$

in which $y_0 = \frac{t(\hat{c})-\eta}{p}$. And $\hat{c}$ is the cost the supplier declares.

Equation (126.4) is the supplier participation constraint to ensure the supplier can receive a nonnegative profit when he tell the truth. Equation (126.5) is the profit for supplier when the supplier pretends to be a c is supplier. Equation (126.6) is the incentive constraint to prevent the $\hat{c}$ is supplier from pretending to be a $\hat{c}$-supplier. Laffont's method [6] is used to solve the model.

Equation (126.5) implies that the following first-order condition for the optimal response $\hat{c}$ chosen by type c is satisfied:

$$\dot{t}\left(\hat{c}\right) - c\dot{Q}\left(\hat{c}\right) - F\left(\frac{t\left(\hat{c}\right)-\eta}{p}\right)\dot{t}\left(\hat{c}\right) = 0. \tag{126.7}$$

For the truth to be an optimal response for all c, it must be the case that

$$\dot{t}(c) - c\dot{Q}(c) - F\left(\frac{t(c)-\eta}{p}\right)\dot{t}(c) = 0. \tag{126.8}$$

Equation (126.8) must hold for all c in $[\underline{c}, \overline{c}]$ as c is unknown to the retailer.

It is also necessary to satisfy the second-order condition:

$$\ddot{t}(c) - c\ddot{Q}(c) - f\left(\frac{t(c)-\eta}{p}\right)\frac{t(c)^2}{p} - F\left(\frac{t(c)-\eta}{p}\right)\ddot{t}(c) \leq 0. \tag{126.9}$$

By differentiating Eqs. (126.8) and (126.9) can be written more simply as:

$$\dot{Q}(c) \leq 0. \tag{126.10}$$

Incentive constraint (126.6) is represented by Eqs. (126.8) and (126.10). Representing the transfer payments with profit, Eq. (126.8) is rewritten as:

$$\dot{\pi}_s(c) = -Q(c). \tag{126.11}$$

The incentive model is therefore changed as follows:

$$P2: \quad \max_{\{(t,Q)\}} \pi_r = \int^{\bar{c}} \left(pQ - t - \int_{y_0}^{Q} pF\,(y)\,dy \right) g\,(c)\,dc$$
$$s.t.\ \text{Eqs. (126.4), (126.10), and (126.11).}$$

Ignoring Eq. (126.10) momentarily, Eq. (126.11) is solved as $\pi_s\,(c) = \pi_s\,(\bar{c}) + \int_c^{\bar{c}} Q\,(\tau) d\tau$. Since $\pi_s\,(\bar{c}) = 0$ can satisfy Eq. (126.4), the retailer does not have to allow the supplier any more profit than 0. So,

$$\pi_s\,(c) = \int_c^{\bar{c}} Q\,(\tau) d\tau. \tag{126.12}$$

The retailer profit becomes $\int^{\bar{c}} \left(pQ - \int_c^{\bar{c}} Q(\tau)d\tau - cQ - \int_0^Q pF(y)dy \right)$ $g(c)dc$, which, through an integration by parts, gives $\int^{\bar{c}} (pQ - \int_0^Q pF(y)dy - \left(c + \frac{G(c)}{g(c)} \right) Q) g(c)dc$. Maximizing this pointwise, the second-best optimal quantity is determined as follows:

$$Q^*\,(c) = F^{-1} \left(\frac{p - \left(c + \frac{G(c)}{g(c)} \right)}{p} \right). \tag{126.13}$$

Since $\frac{G(c)}{g(c)}$ increases with increases in c, the solution $Q^*\,(c)$ in Eq. (126.13) is clearly decreasing. So, the neglected constraint (126.10) is satisfied.

By combining Eq. (126.4), the transfer payment is

$$t^*\,(c) = \left\{ t | t = \int_c^{\bar{c}} Q^*\,(\tau) d\tau + cQ^* + \int_0^{\frac{t-\eta}{p}} pF\,(y)\,dy \right\}. \tag{126.14}$$

The expected profits for the suppliers and retailers, respectively, are as follows:

$$\pi_s{}^* = \int_c^{\bar{c}} Q^*\,(\tau)\,\mathrm{d}\tau, \tag{126.15}$$

$$\pi_r{}^* = \int^{\bar{c}} \left(pQ^* - \int_0^{Q^*} pF\,(\mathrm{y})\,\mathrm{dy} - \left(c + \frac{G\,(c)}{g\,(c)} \right) Q^* \right) g\,(c)\,dc. \tag{126.16}$$

Proposition 126.1 *Under trade credit and adverse selection, the optimal incentive contract can be determined by solving (126.14) and (126.13) using information screening. The expected profits for the suppliers and retailers, respectively, are as in (126.15) and (126.16).*

126.3.2 Model Under Trade Credit and Ssymmetric Information

If the retailer has insufficient funds and trade credit is adopted, under symmetric information the model is as follows:

$$P3: \max_{\{(t_0(c),Q_0(c))\}} \pi_{r0} = \int^{\bar{c}} \left(pQ_0 - t_0 - \int_{y_0}^{Q_0} pF(y)\,dy \right) g(c)\,dc \tag{126.17}$$

$$s.t.\ \pi_{s0}(c,c) = t_0 - cQ_0 - \int_0^{y_0} pF(y)\,dy \geq 0. \tag{126.18}$$

By solving the model, the following proposition is derived.

Proposition 126.2 *Under trade credit and symmetric information, the optimal contract menu* $\{(t_0^*(c), Q_0^*(c))\}$ *is composed of* $t_0^*(c) = \left\{ t_0 | t_0 = cQ_0^* + \int_0^{\frac{t_0-\eta}{p}} pF(y)\,dy \right\}$ *and* $Q_0^*(c) = F^{-1}\left(\frac{p-c}{p}\right)$*. The expected profits for the suppliers and retailers are then* $\pi_{s0}^* = 0$ *and* $\pi_{r0}{}^* = \int^{\bar{c}} \left(pQ_0^* - cQ_0^* - \int_0^{Q_0^*} pF(y)\,dy \right) g(c)\,dc.$

126.3.3 Incentive Model Under Cash Transactions and Adverse Selection

If the retailer has sufficient funds, a cash transaction is adopted and the supplier maintains privacy regarding their costs, so the retailer incentive model is as follows:

$$P4: \max_{\{(t_1(c),Q_1(c))\}} \pi_{r1} = \int^{\bar{c}} \left(pQ_1 - t_1 - \int_0^{Q_1} pF(y)\,dy \right) g(c)\,dc, \tag{126.19}$$

$$s.t.\ \pi_{s1}(c,c) = t_1 - cQ_1 \geq 0, \tag{126.20}$$

$$\pi_{s1}\left(c,\hat{c}\right) = t_1\left(\hat{c}\right) - cQ_1\left(\hat{c}\right), \tag{126.21}$$

$$\pi_{s1}(c,c) \geq \pi_{s1}\left(c,\hat{c}\right). \tag{126.22}$$

The model is solved as follows:

$$Q_1^*(c) = F^{-1}\left(\frac{p - \left(c + \frac{G(c)}{g(c)}\right)}{p} \right), \tag{126.23}$$

$$t_1^*(c) = \left\{ t_1 | t_1 = \int_c^{\bar{c}} Q_1^*(\tau)d\tau + cQ_1^* \right\}, \tag{126.24}$$

$$\pi_{s1}{}^{*} = \int_{c}^{\bar{c}} Q_1^*(\tau)\, d\tau, \tag{126.25}$$

$$\pi_{r1}{}^{*} = \int^{\bar{c}} \left(pQ_1^* - \int_0^{Q_1^*} pF(y)\, dy - \left(c + \frac{G(c)}{g(c)} \right) Q_1^* \right) g(c)\, dc. \tag{126.26}$$

Proposition 126.3 *Under cash transactions and adverse selection, the incentive menu* $\left\{\left(t_1^*(c), Q_1^*(c)\right)\right\}$ *composed of Eqs. (126.24) and (126.23) can achieve information screening. The expected profits for the suppliers and retailers, respectively, are as in Eqs. (126.25) and (126.26).*

126.4 Contract Analysis

In Proposition 126.1, Q^*, π_s^*, and π_r^* are influenced by supplier costs or market demand distribution, but are not influenced by retailer available funds. From Eq. (126.14) we can derive $\frac{\partial t^*}{\partial \eta} = -\frac{F\left(\frac{t^*-\eta}{p}\right)}{\bar{F}\left(\frac{t^*-\eta}{p}\right)}$, which means that when the quantity is constant the transfer payments t decrease with an increase in the retailer holding funds η because when retailer holding funds increase, supplier credit risk decreases.

Conclusion 1. Under asymmetric information, transaction quantities and profits on both sides are not influenced by retailer available funds under trade credit. Transfer payments decrease with an increase in retailer available funds.

As shown in Proposition 126.2, under symmetric information, the retailer gains all profit of the supply chain and the supplier receives nothing. Under this situation the transaction quantities are accordance with an integrated supply chain.

By comparing Propositions 126.1 and 126.2, we derive $t^*(c) > t_0^*(c)$, $t^*(c) > t_0^*(c)$, $\pi_s^* > \pi_{s0}^*$ and $\pi_r^* < \pi_{r0}^*$, which means under trade credit, asymmetric information reduces transaction quantities. If and only if $c =$, does $Q^*(c) = Q_0^*(c)$, which means that for a highly efficient supplier, supply chain efficiency is enhanced. By comparing this situation with a situation under symmetric information, the retailer gains less and the supplier gains more under asymmetric information. From Proposition 126.1, due to the asymmetric information, the higher the supplier efficiency, the greater the benefit the supplier obtains.

Conclusion 2. Under asymmetric information, trading quantities are distorted downwards and the supplier obtains a nonnegative profit which increases with increases in supplier costs.

Contracting Propositions 126.1 and 126.3, we have $t^*(c) > t_1^*(c)$, $Q^*(c) = Q_1^*(c)$, $\pi_s^* = \pi_{s1}^*$, and $\pi_r^* = \pi_{r1}^*$, which shows that under asymmetric information the transaction volumes and the expected profits for trade credit, respectively, are the same as that for trading in cash. This indicates that transfer payments for trade credit are greater than transfer payments for cash trades. Based on this model, the credit risk the supplier bears is $\int_0^{y_0} pF(y)\, dy$, which is related to the retailer available funds and the transfer payments, but not to the supplier private information; therefore, the transaction volumes and expected profits do not change. This means that trade credit does not distort transaction volumes. Conclusion is concluded as follows.

Conclusion 3. Trade credit does not influence supply chain efficiency.

Based on conclusions above, when a supplier has private information about manufacturing cost, the transaction volumes when using trade credit are the same as when using cash trades. To protect a reasonable profit, the supplier could ask for more transfer payments to protect against credit risk.

126.5 Mumerical Study

In this section, we clarify the conclusions and compare the results obtained from trade credit and cash trades under asymmetric information using a numerical approach. The following assumptions are maintained in the simulations: demand y is uniformly distributed with density $f(y) = 1/100$ in the range [0, 100]; the supplier's cost c is uniformly distributed in the range [0.3, 0.5; the base values for the parameters are $p = 1$. Matlab 7.0 was used to calculate the numerical study.

The trading quantity under both trade credit and cash trades is

$$q = 130 - 200c\,(1+\alpha) + 30 \times \alpha. \tag{126.27}$$

The transfer payment under trade credit is

$$t = \eta + 100 - 10\begin{pmatrix} 20(1-\alpha)^2 - 200c^2(1+\alpha)^2 \\ -20\alpha + 60c(1+\alpha)^2 + 2\eta\,(1+\alpha) \end{pmatrix}^{(1/2)}. \tag{126.28}$$

By setting $c = 0.4$ and $\alpha = 0.1$, we can determine the variation trends in transfer payment t with η from $0 \le \eta \le t$, as in the following Fig. 126.2. It can be clearly seen that transfer payment t decreases as η increases.

The transfer payment under a cash trade is

$$t = -10a - 60ca + 40 + 300c^2 + 300ac^2 - 260c. \tag{126.29}$$

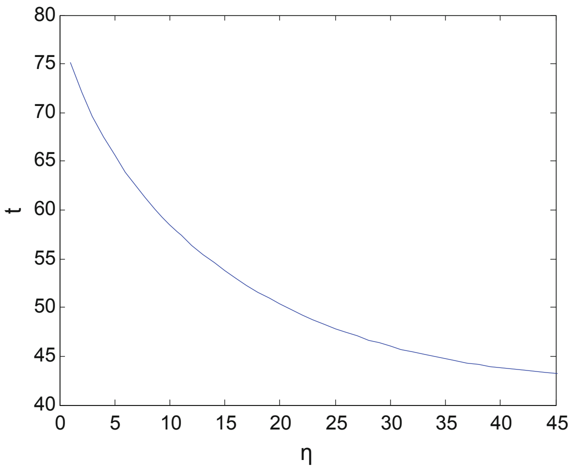
For both trade credit and cash trades, the expected profits for the supplier and the retailer are as follows:

$$\pi_s{}^* = 40 + 100c^2(1+\alpha)^2 + 30a - 10a^2 - 130c - 160ca - 30ca^2, \tag{126.30}$$

$$\pi_r{}^* = \frac{79}{6} - \frac{71}{3}\alpha + \frac{79}{6}\alpha^2. \tag{126.31}$$

It is clear that the transfer payment in the incentive contract offered by the retailer is influenced by retailer available funds. However, trading quantities and expected

Fig. 126.2 Influence of η on t



profits for both the retailer and the supplier are not influenced by retailer available funds. In conclusion, trade credit does not increase or decrease the trading quantity distortion but brings greater loss to the retailer. From the above discussion, the main conclusions are clarified.

126.6 Summary and Conclusion

In this paper, in order to relieve the adverse selection because of the supplier private information, an incentive model was built using principle-agent theory from the perspective of the retailer, under the situation that the supplier bears the credit risk when trade credit is used. The model was solved to determine an optimal contract which was then compared to trade credit under symmetric information and cash trades under asymmetric information, respectively. The results found that an optimal trade credit contract under asymmetric information can stimulate the supplier to tell the truth and force down transaction volumes. An important conclusion was that trade credit was found to have no influence on the efficiency and transaction volumes of the supply chain. This finding is helpful for further research into trade credit incentive contracts. As the retailer may also conceal private information, bilateral adverse selection is a future research focus.

Acknowledgments The paper is supported by the China National Natural Science Foundation (Grant No. 71071103, and No. 71001076), and the Ministry of Education Humanities and Social Sciences Youth Planning Fund, China (Grant No. 14YJC630020), and the Sichuan Provincial Key Research base of Philosophy and Social Sciences-2014 Subject of System Science and Enterprise Development Research Center, China (Grant No. Xq14C02). We thank the anonymous reviewer for their helpful comments.

References

1. Chang C, Cheng M, Ouyang L (2015) Optimal pricing and ordering policies for non-instantaneously deteriorating items under order-size-dependent delay in payments. Appl Math Model 39(2):747–763
2. Chen F (2007) Auctioning supply contracts. Manag Sci 53(10):1562–1576
3. Cheng H, Wang Y, Su Y (2011) Optimal trade credit policy for supplier under asymmetric information in the supply chain. J Donghua Univ (English Edition) 28(4):439–444
4. Goyal SK (1985) Economic order quantity under conditions of permissible delay in payments. J Oper Res Soc 36:335–338
5. He W, Xu F (2013) The coordination mechanism of supply chain and demand network under asymmetric information. Chin J Manag 21:508–512
6. Laffont JJ, Martimort D (2009) The theory of incentives: the principal-agent model. Princeton University Press, Princeton
7. Shah NH, Cárdenas-Barrón LE (2015) Retailer's decision for ordering and credit policies for deteriorating items when a supplier offers order-linked credit period or cash discount. Appl Math Comput 259:569–578
8. Yu D, Luo J (2012) Reverse auction under budget constraints. J Syst Manag 2:007
9. Zhang Q, Lue J (2009) Coordination of supply chain with trade credit under bilateral information asymmetry. Syst Eng Theory Pract 29(9):32–40
10. Zhou Y, Wen Z, Wu X (2015) A single-period inventory and payment model with partial trade credit. Comput Ind Eng 90:132–145
11. Zia NP, Taleizadeh AA (2015) A lot-sizing model with backordering under hybrid linked-to-order multiple advance payments and delayed payment. Transp Res Part E Logist Transp Rev 82:19–37

Chapter 127
Local Government Debt Risk, Fiscal Expenditure Efficiency and Economic Growth

Hong Wang, Jie Huang and Huiyu Li

Abstract Government debt has an impact on economic growth, but there is a big difference when the local government's fiscal expenditure is efficient or not. This paper tries to explicit the impact of local government debt risk on economic growth, in the case of the efficiency of fiscal expenditure. We assess the local government debt risk by the debt ratio and gain the fiscal expenditure efficiency with Data Envelopment Analysis (DEA). The empirical study shows that the relationship between the efficiency of fiscal expenditure and local government debt risk is significantly negative, and the risk of local government debt has a significantly negative impact on the economic growth, with the data of 28 provinces, municipalities and autonomous regions of China for the period 2011–2013.

Keywords Local government debt risk · Fiscal expenditure efficiency · Economic growth · DEA

127.1 Introduction

In the late 1930s, Keynes systematically discussed the economic rationality of the fiscal deficit for the first time in his book "The General Theory of Employment, Interest and Money". He pointed out that the fiscal expenditure could form the effective demand to make up for the insufficient free market demand directly, and it could effectively solve the problem of "market failure". According to Keynesianism, most governments around the world adopted the way of government borrowing to support spending and promote economic development by playing the role of the macroeconomic regulator and controller effectively. However, from a series of events like the

H. Wang (✉) · J. Huang
School of Business, Sichuan University, Chengdu 610064, People's Republic of China
e-mail: wanghong_scu@scu.edu.cn

H. Li
Journal of Sichuan University (Philosophy and Social Science Edition), Chengdu 610064, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_127

Latin American debt crisis of the 1970s, the European sovereign debt crisis erupted in October 2009, the bankrupt of Detroit and the close of the U.S. government happened in 2013, excessive government debt can't promote economic growth and it may cause the economic crisis even. According to The National Government Debt Audit Report released by National Audit Office of China in June 2013, by the end of 2012, the national total government debt ratio is 39.43 %, and the liability ratio is 113.41 % (Debt ratio and liability ratio are the local government debt as a share of GDP and fiscal revenue respectively). Although the local government debt in China is still below the warning line (According to the Maastricht Treaty, the warning line of government debt is 60 %.), there are many problems in the management of Chinese local government debt, such as the shortage of effective management to the state-owned platform companies, mismatch of the debt maturity and the increasing pressure of debt repayment. It is increasingly apparent that Chinese local government debt risk hinders its economic growth.

At present, scholars generally believe that the relationship between government debt and economic growth is "inverted U", that is, when the government debt risk is in a certain threshold range, they have a positive correlation; when the government debt risk is beyond the range, the increase in debt rate will slow down the economic growth [2–4, 6, 8–10]. In order to control the government debt risk effectively, we need to analyze the reasons that cause the risk. Among the previous literatures, whether it is "financial system", "debt management mechanism" or "land financial dependence" [5, 12, 14, 15], they are not concerned about the deeper causes of the government debt risk. Keynesian thought expanding government spending through government borrowing will produce a multiplier effect of consumption, stimulate private sector demand, and promote steady economic growth. It contains a condition in this opinion that the fiscal expenditure needs to play its role effectively. If the fiscal expenditure helps to promote technological progress and industrial upgrading, it can provide a solid foundation and guarantee for local government finance. In the long-term, the local government debt will be safe and benign debt. On the contrary, with the low efficiency of government financial expenditure, governments can not effectively play its regulatory role, promote economic growth, enhance the ability to repay debt, and thus debt risks can not be resolved. Even in the case of government debt scale enlarging, it will lead to the deterioration of risk. Therefore, it can be seen that the main reason for the formation of local debt risk is the low efficiency of financial expenditure, that is, the local financial expenditure can not effectively play its role in promoting economic growth.

In this paper, the data of 28 provinces, municipalities and autonomous regions are studied, and the data envelopment analysis method is used to measure the fiscal expenditure efficiency of the sample from 2011 to 2013. This paper contributes to the literature by expanding the research of local government debt risk in China. It helps to provide a brand-new way to control local government debt risk. It also contributes by investigating the effect of local government debt influenced by the fiscal expenditure efficiency on economic growth, refining the effect of government debt on economic growth, and providing theoretical basis for the realization of more stable regional economic growth.

127.2 Literature Review

The research on the impact of government debt on economic growth can be divided into three stages, including the classical economics period in the eighteenth Century, the Keynesian era of the 1970s and the financial crisis in 2008. Classical economists believe that government spending is non-productive expenditure, and government borrowing will lead the production of capital to a non-productive expenditure, weakening of the national economy. By the 1970s, Keynes doctrine prevailed, scholars generally believed that government debt can expand the behavior of government spending, thus result in the consumption multiplier effect, stimulate the demand of private sectors, and ultimately promote economic growth. Until the 2008 world financial crisis broke out, the government's debt problems aroused wide attention of scholars once again. Reinhart and Rogoff [10] analyzed the correlation between the government debt and economic growth. Then they found that the government debt was not related to economic growth when the debt ratio was lower than 90 %, but when the debt ratio was higher than the critical value, they were significantly negative correlation. Later, scholars used different samples and methods to verify the nonlinear relationship between government debt and economic growth, and draw the different government debt thresholds [2–4, 8]. In China, Liu [6], Qiu [9] and Zhu [16] used the audit report data and different panel regression models. Finally, they found the nonlinear relationship between local government debt and economic growth in China. The conclusion of Liu and Qiu was similar to the main conclusion of the foreign researches, and the relationship is the "inverted U", while Zhu's empirical study showed that they were "positive U" relationship [16]. From this, it can be seen that it is uncontroversial that local government debt has a significant impact on the economic growth, but there is a big difference about what the relationship is.

Reasons of local government debt risk mainly include "financial system", "debt management mechanism" and "land financial dependence". "Financial system" theory says that China's current tax system leads to the mismatching between the local governments' governance and property power. The tax revenue obtained by the local governments can not meet their development needs, so they rely much more on the debts [5, 14]; "debt management" theory says that the non comprehensive budget and loose management of financing platform companies are unfavorable for people to understand the current situation of debt and the use of funds. It causes a huge potential risk [12]; "Land Finance Dependence" theory says the local governments' ability to acquire funds through land finance is getting weak, because the reduction of transferable land use rights results in a decline in the solvency [15]. According to the basic financial theory, the function of local finance is public service and economic construction. On the one hand, effective fiscal expenditure can lay the foundation for the long-term development of regional economy by improving the infrastructure, the level of medical and education, and the quality of the environment. Xi and Ye [13], Liu and Tang [7], Afonso and Fernandes [1] used DEA method to evaluate the efficiency of local government fiscal expenditure, and analyzed the efficiency of the target region in the current situation. But the literature on the impact of fiscal expenditure efficiency on government debt risk is currently very little. The study on the relationship between the former two is much less, in case of the efficiency of fiscal expenditure. This will be the main contribution of this paper.

127.3 Measurement of the Efficiency of Fiscal Expenditure

Data Envelopment Analysis (DEA) is a kind of evaluation method based on the concept of "relative efficiency". The general relation of the financial expenditure efficiency of the local government can be expressed as follows:

$$Y_i = f(X_i), \quad (i = 1, \ldots, n). \tag{127.1}$$

In Eq. (127.1), Y_i represents the output and X_i indicates the financial expenses of a local government. In particular, in the model, n DMUs (Decision Management Unit) are assumed to exist, each of which has k inputs and m outputs. For the ith DMU, X_i is expressed as the input vector, and the Y_i is expressed as the output vector. X is defined as the input matrix ($k \times n$), and Y is defined as the output matrix ($m \times n$). Under the assumption of inconstant returns to scale, the input efficiency of the ith DMU can be solved by the following mathematical programming:

$$\begin{aligned} &\min \theta, \lambda^{\theta} \\ &s.t. \begin{cases} -Y_i + Y^{\lambda} \geq 0 \\ \theta X_i - X^{\lambda} \geq 0 \\ e^{\lambda} = 1, \lambda > 0. \end{cases} \end{aligned} \tag{127.2}$$

According to the definition, the frontier is a linear combination of DMU. In the formula, θ is a scalar, meeting $\theta \leq 1$. It measures the distance of a local government to the frontier. If $\theta < 1$, it implies the local government fiscal expenditure is within the frontier, in invalid state. If $\theta = 1$, it shows that fiscal expenditure of local governments located just on the frontier, in valid state. To be sure, effective DMU is reference object to ineffective DMU.

This paper measures local government's fiscal expenditure efficiency with the input variable, fiscal expenditure per capita, and the output variables, such as government agencies and government corruption, drawing on Afonso's analysis framework of the two basic functions which are the government public governance and economic development, and Liu Zhenya's establishment of the index system. We also take the effect of environmental protection and social security into account for a more comprehensive assessment. Calculating the provinces' BCC-O efficiencies by MAXDEA, the results are shown in Table 127.1.

Table 127.1 Results of financial expenditure efficiency evaluation based on DEA

Region	2011	2012	2013	Average	Region	2011	2012	2013	Average
Beijing	0.9809	0.9526	1	0.9778	Henan	1	1	1	1
Hebei	0.8519	0.8877	0.931	0.8902	Hubei	1	0.998	0.9786	0.9922
Shanxi	0.841	0.7511	0.7671	0.7864	Hunan	0.8812	0.8928	0.8819	0.8853
Inner Mongolia	0.7486	0.8196	0.7894	0.7858	Guangdong	1	1	1	1
Liaoning	0.8086	0.878	0.8898	0.8588	Guangxi	0.8132	0.8344	0.9198	0.8558
Jilin	0.8349	0.8506	0.8319	0.8392	Hainan	0.7592	0.7598	0.7536	0.7575
Heilongjiang	0.8534	0.8493	0.8867	0.8631	Chongqing	0.779	0.9403	0.8835	0.8676
Shanghai	1	0.9941	1	0.998	Sichuan	0.8621	0.8992	0.934	0.8984
Jiangsu	0.8463	0.9101	0.825	0.8605	Yunnan	0.7717	0.7821	0.8413	0.7984
Zhejiang	0.9131	0.9269	0.9591	0.933	Shanxi	0.8133	0.8084	0.7124	0.778
Anhui	0.8175	0.821	0.8169	0.8184	Gansu	0.7315	0.7215	0.7282	0.7271
Fujian	0.783	0.7608	0.809	0.7842	Qinghai	0.8	0.8391	0.8134	0.8175
Jiangxi	0.9159	0.9162	0.8586	0.8969	Ningxia	0.6962	0.8514	0.7706	0.7727
Shandong	0.9297	0.9226	0.9035	0.9186	Xinjiang	0.8526	0.7323	0.807	0.7973

127.4 Research Design and Data Sample

127.4.1 Research Design

Among the Empirical researches on the impact of local government debt on economic growth, the majority of them used the combination of linear and nonlinear regression model to verify the "inverted U" relationship between government debt and economic growth. The attempt of this paper is to explore whether government debt has a different impact on economic growth when it is influenced by fiscal expenditure efficiency. We learned from Liu Jinlin's research model, and added the efficiency of financial expenditure as a dummy variable to reflect the cross impact to the risk of government debt. The basic model is as follows:

$$\mathrm{RGDG}_u = \alpha \mathrm{Risk}_{it} + \beta \mathrm{Risk}_{it} \times \mathrm{Eff}_{it} + \gamma \mathrm{RGDP}_{it-1} + \varphi X_{it} + \varepsilon. \qquad (127.3)$$

It needs to be explained that, economic growth and real GDP per capita in the model are divided by the CPI index to eliminate the impact of price factors. Fiscal expenditure efficiency is a dummy variable, so this article defines provincial fiscal expenditure efficiency as 1 when the value is equal to 1; otherwise, we defines it as 0. Sala-i-Martin [11] tested 67 variables those affect economic growth through establishing cross panel data, and ranked the variables according to the significance of regression coefficient. The result shows the actual GDP variable, trade dependence degree and education level are significant variables [11], so this paper cites these three variables as control variables. According to the new classical economics theory, capital stock and human capital are important factors that affect the economic growth,

Table 127.2 Variable definitions and descriptions

Nature	Symbol	Definition	Method	Source
Dependent	RGDG	Growth rate of economic	The average of next two years' real GDP growth	China statistical yearbook
Independent	Risk	Debt risk	Debt: total government debt/GDP	The national government debt audit report, China statistical yearbook
Cross	Eff	Fiscal expenditure efficiency	Data envelopment analysis	China statistical yearbook
Control	RGDP	Real GDP per capita	Real GDP per capita	China statistical yearbook
	INF	Inflation rate	The growth of consumer price index	China statistical yearbook
	TRO	Trade dependency	Exports/GDP	China statistical yearbook
	PHD	Education degree	The population of high school degree/Regional population	China statistical Yearbook
	GFR	Fixed asset investment rate	The whole society fixed assets investment/GDP	China statistical Yearbook
	PGR	Growth rate of population	The natural population growth rate	China statistical Yearbook

so the paper also takes fixed asset investment ratio and population growth rate as the capital stock and human capital's proxy variables, as the control variables. Reinhart and Rogoff [10] conducted a study of the impact of government debt on economic growth, taking the impact of inflation into account, so this paper takes the inflation rate as a control variable based on the robustness. In this paper, the trade dependence, education degree and fixed asset investment ratio are natural logarithm processed. Detailed definitions and descriptions of variables are shown in Table 127.2.

127.4.2 Data Sample

Because of the lack of data of Tianjin, Guizhou and Tibet, they are not used as research samples in this paper. Thus, this paper finally gets 28 provinces, municipalities and autonomous regions for the period 2011–2013 as the research samples.

127.5 Empirical Test and Results

127.5.1 Descriptive Statistics

Variable descriptive statistic results are shown in Table 127.3, on the whole, the level of the national debt rate is 31.65 %, and there is a distance to the international warning line. However, Chongqing's debt ratio in 2013 is 63.3 %, so Chongqing is a high-risk province in government debt. In Chongqing, the debt ratios are 55.32, 58.68 %, respectively in 2011 and 2012, very close to the warning line. In contrast, in Shandong and Henan, the debt ratios of three years are at low level, which means the risk of their government debts are still under control. In terms of the efficiency of fiscal expenditure, Guangdong province has achieved efficient fiscal expenditure in three consecutive years for 2011–2013, followed by Shanghai, which achieved efficient fiscal expenditure in both 2011 and 2013. Oppositely, Gansu and Hainan province are inefficient in fiscal expenditure for three consecutive years, far below the average level of 0.8628.

In order to demonstrate the effect of the fiscal expenditure efficiency on the government debt risk, this paper analyzes the descriptive statistics distinguishing the efficient and inefficient fiscal expenditure. At the same time, this paper shows the current situation of the regional government debt risk, the efficiency of fiscal spending and economic growth rate by analyzing the East, Middle and West regions separately. As shown in Table 127.4, the debt rate of efficient group is lower than that of the inefficient group, the real GDP per capita is higher, and the actual GDP growth rate is lower. As can be seen in the following table, the higher the efficiency of financial expenditure is, the lower the risk of government debt is. According to the results of the regional group, from East to West, fiscal expenditure efficiency and real GDP per capita are getting lower and lower, and the actual GDP growth is growing rapidly. For the government debt risk, the West's risk is the highest, and the Central's is the lowest. Generally, it still shows the higher the efficiency of the financial expenditure is, the lower the risk of government debt is.

Table 127.3 Descriptive statistics of variables

Variable	Average	Minimum	Maximum	Standard deviation	N
RGDG	0.111832	0.0251	0.1815	0.0343984	84
Risk	0.316551	0.1142	0.633	0.1180393	84
Fin	0.862821	0.6962	1	0.0848713	84
RGDP	5.83374	5.023	6.742	0.402513	84
INF	−0.002065	−0.0405	0.0316	0.0197832	84
TRO	5.014254	3.1861	6.996	0.9691886	84
PHD	8.432708	6.2086	9.7505	0.7884285	84
GFR	−0.385893	−1.3721	0.1067	0.322049	84
PGR	5.2123	−0.39	10.92	2.58162	84

Table 127.4 Descriptive statistical results

Variable	Fiscal expenditure efficiency group		Regional group		
	Effective (Fin = 1)	Ineffective (Fin ≠ 1)	East	Middle	West
RGDG	0.0946	0.1142	0.1028	0.1104	0.1291
Risk	0.2453	0.3262	0.297	0.2744	0.4042
Fin	1	0.8443	0.8918	0.8742	0.7985
RGDP	6.0982	5.798	6.0961	5.7282	5.5197
INF	0.0032	−0.0028	−0.0023	−0.0016	−0.0023
TRO	5.8542	4.9007	5.802	4.3621	4.5022
PHD	9.0796	8.3453	8.6115	8.7183	7.7589
GFR	−0.8441	−0.324	−0.582	−0.2888	−0.1746
PGR	4.828	5.2642	4.8775	4.5	6.7019
N	10	74	36	27	21

127.5.2 Regression Results

Empirical results about the impact of government debt risk influenced by the efficiency of fiscal expenditure on economic growth are shown in Table 127.5. Results (I) shows that government debt has a significant negative effect on the economic growth at 1 % level currently. If the fiscal expenditure is effective, it can weaken the negative effect of government debt on economic growth, but the coefficient is not significant. According to the results of (II)–(VI), which are the products by reducing the number of control variables one by one, the lag phase of real GDP per capita is always a significant negative correlation with economic growth, which verifies the economic growth convergence rule, so the lower initial GDP per capita is, the faster the convergence to the equilibrium point is. In addition, education level, fixed asset investment rate and population growth rate are significantly negatively related to economic growth. The inflation rate is significantly positive while the number of control variables is less. The impact of trade dependence on economic growth is always not significant.

127.5.3 Further Test

Because of the cross effect of fiscal expenditure efficiency is not significant, the paper tries to establish a multiple linear regression equation with the efficiency of fiscal expenditure as independent variable and the risk of local government debt as the independent variable, in order to further examine whether the efficiency of fiscal expenditure will affect the local government debt risk. According to three theories of "financial system", "debt management mechanism" and "land financial dependence", the paper selects the fiscal decentralization (Power), fixed asset investment (Manage)

Table 127.5 The impact of government debt risk on economic growth under the influence of fiscal expenditure efficiency

	(I)	(II)	(III)	(IV)	(V)	(VI)
Risk	−0.1008	−0.095	−0.1834	−0.1473	−0.1573	−0.1665
	−2.94***	−2.68***	−4.98***	−4.27***	−4.65***	−4.79***
RiskEff	−0.0256	−0.0213	0.0078	0.0092	0.013	0.0268
	−1.03	−0.82	−0.26	−0.3	−0.43	−0.86
RGDP	−0.1118	−0.1014	−0.1023	−0.1058	−0.0966	−0.1042
	−10.43***	−9.76***	−8.42***	−8.56***	−9.06***	−9.85***
INF	0.1206	0.1644	0.2303	0.2373	0.2509	
	−1.48	1.97**	2.42**	2.42**	2.54**	
TRO	0.0016	−0.0027	0.0113	0.0083		
	−0.27	−0.48	−1.9	−1.4		
PHD	−0.02	−0.0135	−0.0165			
	−3.14***	−2.23**	−2.33**			
GFR	−0.075	−0.0802				
	−5.12***	−5.34***				
PGR	−0.0047					
	−2.62***					
ε	0.9535	0.8308	0.8499	0.7346	0.7252	0.7718
	12.22***	12.67***	11.11***	12.04***	11.87***	12.79***
N	84	84	84	84	84	84

*, **, *** denotes significance at 10, 5 and 1 % level respectively

and land transfer income (Land) as the control variable. Establish the following model:

$$\text{Risk} = \alpha \times \text{Eff} + b \times \text{Power} + c \times \text{Manage} + d \times \text{Land} + e. \tag{127.4}$$

Because of the incomplete data of the land-transferring fees, this paper finally gained 40 research samples of the 28 provinces, municipalities and autonomous regions for 2011–2013 (Table 127.6).

The results show that the negative correlation between the efficiency of fiscal expenditure and the government debt risk is significant at the 1 % level, that is, the higher the efficiency of fiscal spending is, the lower the risk of local government debt is. In addition, a significantly negative correlation is between debt management and local government debt risk, and the impacts of fiscal decentralization degree and land dependence are not significant. The main reason for the insignificance might be the difference among provinces' decentralization degree is not obvious, with a large proportion of authority and fiscal power are controlled by the central government. Meanwhile, the provinces' dependence on the land finance maintains at a high level for a long-term. These results show that the efficiency of fiscal expenditure can affect the local government debt risk, thereby affect the local economic growth.

Table 127.6 The impact on the efficiency of fiscal expenditure on the risk of government debt

	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Standard deviation			
Constant	1.067	0.131		8.15	0
Eff	−.589***	0.165	−0.434	−3.561	0.001
Power	−0.003	0.019	−0.023	−0.161	0.873
Manage	−.071***	0.012	−0.697	−5.764	0
Land	0.06	0.063	0.107	0.942	0.353

*, **, *** denotes significance at 10, 5 and 1 % level respectively

Table 127.7 The impact of government debt risk (liability ratio) on economic growth under the influence of fiscal expenditure efficiency

	(I)	(II)	(III)	(IV)	(V)	(VI)
Risk2	−0.071	−0.0075	−0.0185	−0.0176	−0.0185	−0.0182
	−1.78***	−1.83***	−4.48***	−4.34***	−4.99***	−4.66***
Risk2Eff	−0.0038	−0.0036	0.0002	0.0005	−0.0003	0.0022
	−1.12	−1.00	−0.05	−0.12	−0.07	−0.53
RGDP	−0.1182	−0.1073	−0.1129	−0.1124	−0.1091	−0.1192
	−10.90***	−10.47***	−9.32***	−9.32***	−10.61***	−11.50***
INF	0.149	0.1941	0.2979	0.2996	0.3062	
	−1.77	2.25**	3.10**	3.09**	3.20**	
TRO	0.002	−0.0058	0.005	0.0034		
	−0.34	−1.01	−0.76	−0.54		
PHD	−0.0134	−0.0081	−0.0076			
	−2.18***	−1.40**	−1.10**			
GFR	−0.0822	−0.0846				
	−5.33***	−5.40***				
PGR	−0.0043					
	−2.29***					
ε	0.9376	0.8256	0.8641	0.8027	0.8029	0.8598
	11.65***	12.23***	10.89***	13.05***	13.12***	13.86***
N	84	84	84	84	84	84

*, **, *** denotes significance at 10, 5 and 1 % level respectively

127.5.4 Robustness Test

The essence of local government debt risk is the probability that local government as a debtor is unable to repay principal and interest to the creditors. Quantifying the risk of local government debt usually uses two indicators of debt ratio and liability ratio. Among them, the debt ratio is the ratio of local government debt and the local GDP, and the liability ratio is the ratio of local government debt and local government

Table 127.8 The efficiency of fiscal spending on government debt risk (liability ratio), the impact of empirical results

	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Standard deviation			
Constant	8.303***	1.322		6.282	0
Eff	−2.906*	1.67	−0.233	−1.739	0.091
Power	−0.779***	0.187	−0.648	−4.168	0
Manage	−0.452***	0.125	−0.48	−3.611	0.001
Land	−0.645	0.638	−0.126	−1.012	0.319

*, **, *** denotes significance at 10, 5 and 1 % level respectively

fiscal revenue. For robustness, this paper will take the liability rate as a measure of local government debt risk, and then carry out the test of the above two models. The conclusion shows that the efficient financial expenditure can effectively reduce the risk of local government debt, and then accelerate the local economic growth. Specific results are shown in the Tables 127.7 and 127.8.

127.6 Conclusion

This paper analyzes the impact of government debt risk on economic growth under the influence of local government fiscal expenditure efficiency by using the data of 28 provinces, municipalities and autonomous regions of China during the period of 2011–2013. The main conclusions of this paper are as follows: on the one hand, the higher the efficiency of financial expenditure is, the lower risk of government debt is. China's west region has the lowest fiscal expenditure efficiency and the highest government debt risk. It should be the key area to be supervised in the local government debt risk in the new situation. On the other hand, the efficiency of fiscal spending and government debt risk is significantly negative correlation, the risk of government debt and regional economic growth are significantly negatively correlated. That is, the higher the efficiency of financial expenditure is, the lower the risk of local government debt is, and then the faster the economic growth is, forming a virtuous circle.

Under the current situation, the local governments still borrow large amounts of debt through various ways, however, government debt is a double-edged sword, and no government can get endless debts. In order to realize stable and rapid development of regional economy, the risk of local government debt must be controlled in a certain range. In terms of measures to ease the debt risk, in addition to focusing on the financial system, the government debt Early Warning System and other aspects, we also need to improve the efficiency of local government financial expenditure. Effective fiscal expenditure can not only improve the region's infrastructure construction, the level of medical education, and the quality of the local environment, but also moderately reduce the borrowing demand, so as to obtain funds to repay the debt and lay the foundation for the long-term development of the regional economy.

Acknowledgments This study is founded by Sichuan University (skqy201523, skzx2015-sb112).

References

1. Afonso A, Fernandes S (2008) Assessing and explaining the relative efficiency of local government. J Socio Econ 37(5):1946–1979
2. Afonso A, Jalles JT (2013) Growth and productivity: the role of government debt. Int Rev Econ Financ 25:384–407
3. Egert G (2013) Economic growth and nonlinear effects: myth or reality (4157)
4. Kumar M, Woo J (2010) Public debt and growth. IMF working papers, pp 1–47
5. Li S, Lin S (2011) The size and structure of China's government debt. Soc Sci J 48(3):527–542
6. Liu J (2013) Research on reasonable government debt scale from angle of economic growth: evidence from OECD. Econ Probl 12:25–30 (in Chinese)
7. Liu Z, Tang T, Yang W (2009) Efficiency measurement of provincial expenditure: DEA technique. Econ Theory Bus Manag 7:50–56 (in Chinese)
8. Presbitero AF (2012) Total public debt and growth in developing countries. Eur J Dev Res 24(4):606–626
9. Qiu L, Fu R, Li F (2015) A study on moderate government debt from the perspective of economic growth: based on the analysis of the county-level panel data of one Chinese western province. NanKai Economic Studies 1:13–31 (in Chinese)
10. Rogoff K, Reinhart C (2010) Growth in a time of debt. Am Econ Rev 100(2):573–578
11. Sala-i Martin X, Doppelhofer G, Miller RI (2004) Determinants of long-term growth: a bayesian averaging of classical estimates (BACE) approach. Am Econ Rev 94:813–835
12. Wang S (2014) Try to talk about local government financing platform risk prevention. Chang J 6:78–82 (in Chinese)
13. Xi P, Liu Y (2014) A study on the impacts of fiscal decentralization on fiscal expenditure efficiency. Contemp Financ Econ 12:139–143 (in Chinese)
14. Xu J, Zhang X (2014) China's sovereign debt: a balance-sheet perspective. China Econ Rev 31:55–73
15. Zhang P (2013) On the debt repayment problem of China's local governments in the post-land finance Era. Contemp Financ Econ 1:39–47 (in Chinese)
16. Zhu W (2014) A study on nonlinear relationship between debt China of local government and regional economic growth. Collect Essays Financ Econ 12:24–30 (in Chinese)

Chapter 128
An Empirical Study on the Influence of the Corporate Social Responsibility to Stakeholders

Xiaoping Li

Abstract How do enterprises fulfill their social responsibilities, will have certain impacts on stakeholders, and to be specific, influencing the external stakeholders' supports to the enterprises. In this paper, based on the researches of the stakeholders and corporate social responsibility, the author propose a presumptive model of the influences of corporate social responsibility behaviors to external stakeholders on the perspective of enterprises' soft powers, and the author has checked the relevant hypotheses on the bases of empirical investigations and data analysis.

Keywords Corporate social responsibility · Stakeholder · Corporate soft power · Corporate competitiveness

128.1 Introduction

In recent years, with the development of economy and Internet technology, the competitions between enterprises has gradually altered from products-oriented and consumer-oriented to Business ecosystem-oriented. The enterprises' behaviors as proactively assuming its responsibility to the environment, society, and community, can help them to build better images, and enhance their competitiveness [1]. The proposition of Theory of Stakeholders provides a new perspective to define the corporate social responsibility. Servaes and Tamayo [2] has analyzed the connotation of the corporate social responsibility from the perspective stakeholders. From the perspective of stakeholders, Zhang [3] has proved that corporate social performance can better financial performance.

Previous researches mainly explain corporate social responsibility merely from the perspective of "corporate citizens". It is of great importance for the enterprises to selectively fulfill their social responsibilities and then enhance their competitiveness

X. Li (✉)
Business School, Sichuan University, Chengdu 610065, People's Republic of China
e-mail: 739278537@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_128

by utilizing Correlation Analysis and Structure Analysis to check and analyze the influences of corporate social responsibility to stakeholders on the perspective of enterprises' soft powers.

128.2 Literature Review and Research Hypothesis

128.2.1 The Theory of Corporate Social Responsibility

The Theory of Corporate Social Responsibility (CSR) was firstly proposed by Sheldon. He thinks that the corporate should combine corporate social demands; The corporate social responsibility contains moral factors, and its service to the community will help to enhance the profit of the community. In 1953, Howard R. Bowen, the American "Father of Corporate Social Responsibility" defined the conception of Corporate Social Responsibility for the first time as "the businessman's social responsibilities" are that "businessman has the responsibility to determine polices, make decisions, and take actions in accordance with the social sense of values and for the purpose of the social benefits" [4]. In Davis's "The Rule of Responsibility", he thinks that the responsibilities of the businessman should be equal to the social rights. He also suggests that while assuming the responsibility of "society-economy", the businessmen should also assume the responsibilities of "society-mankind". In other words, their responsibilities should not be limited in the economic fields, but the non-economic fields. Friedman [5] thought that given an enterprise has obeyed the commercial rules, then its only social responsibility is to maximize the interests of the stakeholders. Carroll thought that the financial responsibility of an enterprise is superior to its social responsibility. McGuire [6] thought that as the prime responsibility an enterprise should assume, the financial responsibility should be emphasized, but at the same time, the enterprises should also pay attention to their social responsibilities. Carroll [3] has given relatively precise definition of Corporate Social Responsibility based on the previous researches. He thinks that Corporate Social Responsibility is the corporates' expectation to organizations, including financial expectation, legal expectation, moral expectation, and free-action expectation. In its essence, this thought has divided an enterprises' social responsibilities into four faces, as financial responsibility, legal responsibility, moral responsibility, and charitable responsibility and then improved the contents of Corporate Social Responsibility. For enterprises, the financial responsibility is fundamental, and the social responsibility is self-determined [7].

128.2.2 Stakeholders and Their Classification

In Penrose's Enterprise Growth Theory, the author puts forward the concepts that enterprise is the collection of human resources and human relationships, which laid the foundation of the stakeholder theory [8]. In 1963, Stanford University Research Institute clearly put forward the definition of the stakeholders, who are those groups, without their support, the organization cannot survive. But this definition, only considering the unilateral effect of stakeholders, does not fully consider the interaction between twos. Eric Rhenman proposed a more comprehensive definition: "the stakeholders of enterprises rely on the enterprise to achieve their personal goals, vice versa, enterprises also rely on stakeholders to survive" [9], This makes the definition of stakeholder theory an independent branch of the theory. In the subsequent development, Freeman's view is of the most representative. In his Strategic Management: A stakeholder approach, Freeman proposed that stakeholders are those who can influence the realization of an organizational goal, or by an organization to achieve its goals of all individuals and groups. This definition further improved the content of stakeholders [10].

About the studies on the classification of stakeholders, general methods are Bevel Subdivision and Mitchell Score. Freeman [9] has divided the stakeholders from three different categorizations as ownership, economic dependence and social interests of stakeholders [11]. Frederik (1988) has divided stakeholders into direct stakeholders and indirect stakeholders, basing on whether they have direct marketing with enterprises. On the basis of comprehensive analyses of previous research, this study suggests that the external stakeholders mainly includes consumers, competitors and partners (suppliers, retailers, etc.), public/media, government/community.

128.2.3 The Relations of Behavior of CSR and Stakeholder

On one hand, the existence social costs of enterprises requires enterprises to assume their responsibilities. Zhu [12] thought corporate social cost problems does not only refer to enterprise social cost, or external cost, but the proper utilization of the social resources can make enterprises to make minimum social welfare, and cause net loss of social welfare. While social cost problems of modern enterprises reflect the economic conflict of the direct stakeholders, including big shareholders, who control enterprises, small shareholders, workers, consumers, and suppliers, and indirect stakeholders [11]. On the other hand, according to the Stakeholder Theory, it is easy to notice that there are great asymmetries of information between business and stakeholders. The stakeholders want to convey a signal to indicate that they are trustworthy, and corporate social responsibility is such signaling mechanism. Through social responsibility, the enterprises can obtain trust and support from stakeholders and contracts provide enterprises and stakeholders with various rights and responsibilities maintain long-term relationships with stakeholders; stakeholders believe that enterprises are “a collection of contracts”. Through formal or informal systems, these to each other.

To obtain resources and a good business environment from all stakeholders, enterprises have to bear the responsibility, safeguard their rights and interests. At the same time, through CSR, enterprises can reduce risk, waste and improve relationships with regulators, enhance brand reputation, increase employee productivity and reduce the cost of financing, so as to create greater business value [13].

Clarkson [4] has proposed that by testing the satisfaction of stakeholders to evaluate the level of corporate social responsibility, and the study shows that corporate social responsibility and stakeholders are directly related [14]. Enterprises, as production business organizations, their economic functions are providing various useful products and service to market. In the pursuit of maximizing their interests, they also will produce various effects on external stakeholders, including ecological damage, and pollution. These negative effects must influence objective evaluation of the external stakeholders to enterprises, leading to such consequences as Government weakens its policy supports, media highlight negative news of enterprises, and gradual loss of value to the public. And external stakeholders, as one of the most important guarantee of the market competitiveness of enterprise, need score for the enterprises, by observing the behavior enterprises and then show their support and satisfaction to the enterprises.

The previous researches, more from empirical research on enterprises, have provided powerful evidence to illustrate why enterprises should bear social responsibility. But the shortcomings is that this theory does not take stakeholders into consideration. There are studies have based on the stakeholders theory to explain why enterprise have to bear social responsibility and how to bear. These studies have made some scientific explanations, but concerning enterprise has varieties of stakeholders, these studies cannot obtain the precise effects of different CSR to the stakeholders. Thus, it is of significant importance to further the study of the effects of social responsibility relationships to stakeholders, by empirical research and analysis of a specific social responsibility, to selectively choose their actions and then enhance enterprises’ competitiveness.

128.2.4 Research Hypotheses

Based on above theory, we can see that to undertake social responsibility is the inevitable choice for enterprise to maintain sustainable business. Enterprises’ external stakeholders in companies, which can be seen as an external oversight body who can monitor whether the enterprises have fulfilled their social responsibilities voluntarily and actively. And corporate social responsibility will have a feedback to the various external stakeholders. As shown in Fig. 128.1: This study suggests that economic and legal responsibilities are the foundation of the enterprises. Initiative to carry out economic and legal responsibilities will give an important return to shareholders, and it also the main consideration for the continued support from the

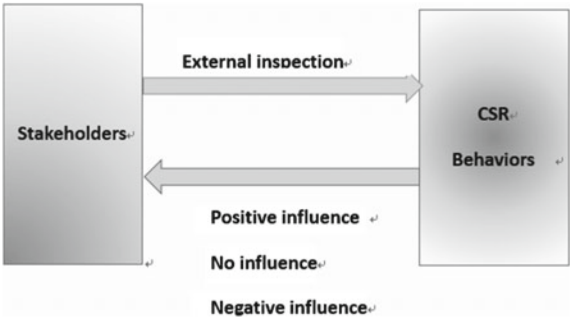


Fig. 128.1 The interactive relationship between corporate behaviors and stakeholders

shareholders. To be specific, these performances are that enterprises should strictly abide by the relevant laws and regulations, and be responsible for security and return for shareholders' funds, and to provide shareholders with true and reliable information on business and investments; in addition, enterprises' responsibilities of charity and business ethic are advantageous strengths. These two social responsibilities are selective, and mainly faced with the external stakeholders. The study shows that for consumers, they are more likely to buy products which are made by enterprises actively assuming their responsibilities [15]. Xie and Zhou et al. [16] argued that corporate social responsibility not only have a direct positive impact on consumers' purchase intentions, but also have an indirect positive effect on consumer purchase intention through good corporate reputations and consumer's identity of the enterprises. And the indirect impact is much larger than the direct effects [17]. Since enterprises can get profit by providing consumers with products and services, to maximize their profits, the enterprises must maximize the consumers' purchase ability. Thus enterprises have to actively assume their responsibilities of qualities of products and services. For competitors, through performing more charity responsibilities and to get more social identity and trust, enterprises can win more supports from consumers gain potential consumers, and finally upgrade their market competitiveness. For cooperation partners, through actively bear on their responsibilities for cooperation partners (as suppliers), inviting suppliers to participate in the development of products, strengthening their information communication and exchange, committing to build long-term strategy partners relationship with the suppliers, enterprises can establish more consolidated relationship with suppliers and get more of supports. For government and community, through obeying laws and official rules, legal management, paying tax by law, and other responsibilities as defined by the government rule or laws; and burden on their responsibilities for the community, enterprises can get supports from government and communities. For the public and media, primarily through active the implementation of the four responsibilities of enterprises, establishing a positive corporate image in society, enhancing their reputation, enterprises can gain supports from public and media.

Therefore, based on the study of the interviews, this paper makes the following assumptions:

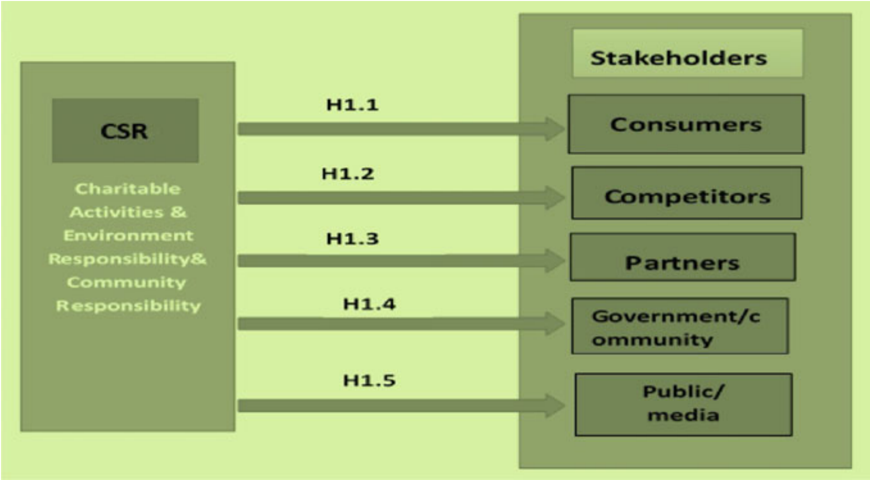


Fig. 128.2 Hypothesis

Hypothesis 1 (H1): Corporate Social Responsibility is significantly positively correlated with stakeholders;

Hypothesis 1.1 (H1.1): Corporate Social Responsibility is significantly positively correlated with consumer behaviors;

Hypothesis 1.2 (H1.2): Corporate Social Responsibility competition is significantly positively correlated with the avoidance of rivals;

Hypothesis 1.3 (H1.3): Corporate Social Responsibility is positively correlated with access to continuing strategic cooperation partners

Hypothesis 1.4 (H1.4): Corporate Social Responsibility is positively correlated with policy supports from government and community;

Hypothesis 1.5 (H1.5): Corporate Social Responsibility is positively correlated with the supports from public/media (Fig. 128.2).

128.3 Study Design and Data Analysis

For the further research on impacts of corporate social responsibility on the supports of stakeholders, this paper has finished scale design by drawing on the researches of others, basing on interview results. The survey is based on theoretical assumptions and scale design; according to the valid questionnaires recovered, dates are processed and SPSS20.0 canonical correlation analysis of the data is utilized to analyses dates; EQS6.1 is utilized to check the hypothesis of structural equation models.

128.3.1 Survey Design and Questionnaire Development

The survey has three major components, including basic information questionnaire respondents, corporate social responsibility, and stakeholder impacts. Taking into account the practical limitations of irreparable defects in scale development, this study conducted two surveys: for the first time, the purpose of the survey is for calibrating, and correcting table of items and adjusting it accordingly; the second survey focuses on data analysis, aiming to test the hypothesis. Questionnaire utilizes Likert 7 scoring method.

(1) The development of scale design of Corporate Social Responsibility

Corporate social responsibility is optional rather than compulsory, which companies have voluntary compliance initiative. At present, because of objective factors as the low cost of information disclosure, and its high efficiency; and subjective factors as enterprises need to gain social acceptance, society and enterprises will maintain a high degree of concern for social responsibility. What is more, a few fast-growing enterprises, or listed companies (such as BoE technology group joint-stock company, Datang international power generation Co Ltd) have already published reports about the corporate social responsibility. On the measurement of corporate social responsibility, scholars at home and abroad are relatively mature, for example, when reporting corporate social responsibility, most enterprises have listed such index as "charity, community interaction, environmental responsibility", and so on. In this paper, based on the study results of [8, 16] and combining with experts interviews, a few indexes easy to be observes are selected to measure corporate social responsibility as shown in Table 128.1.

(2) The development of scale design of influence of stakeholders

Divided according to the above five categories of stakeholders, referencing to the previous scale design, and combined with interviews of experts, a scale design is formed as shown in Table 128.2 to measure the impacts on stakeholders.

128.3.2 Questionnaire Distribution and Data Collection

Questionnaire includes all levels of employees of enterprises (Senior, Middle, General Manager and senior technical staff, Mid-level technicians and Junior technical personnel), The investigated cover an education structure of the doctor, graduate, undergraduate, college/technical secondary school and below. In order to ensure the coverage of the survey as widely as possible, questionnaire are covering the State-owned enterprises, private enterprises, foreign-funded enterprises, collective enterprises and joint ventures, and so on. Business scales cover large, medium and small scale enterprises, and mainly small and medium enterprises. Two surveys have totally issued 600 questionnaires, and 404 are valid, making effective recovery of 67.3 %. In the sample population, to ensure the validity of the questionnaire, 95.8 % are of college or junior college degree or above. In the distribution of posts, 69.3 %

Table 128.1 Results analysis

	Factor	Index
Corporate social responsibility behaviors	Charity A_1	X_1 = there is quantitative standard about enterprises' donations
		X_2 = enterprises have organized employees to donate blood
		X_3 = enterprises have donated or organized employees to donate money to disaster areas
	Community responsibility A_2	X_4 = enterprises have provided community with some conveniences such as discounts of products, and occupations
		X_5 = enterprises have actively supported the activity of the community
	Environment responsibility A_3	X_6 = enterprises have taken some measures as voluntarily try to decrease energy consumption
		X_7 = enterprises do not have negative world records as pollute the environment

are in the management level, reflecting the dependability of data obtained, and to be specific, middle managers and first-line managers and mid-level technical staff accounted for 42.3, 24.3 and 17.3 %, respectively. Since the distribution of positions in the work unit is in accordance with distribution of the works, it can reflect the general situation (Table 128.3).

128.3.3 Data Analysis

Through the analysis of the reliability and validity of the data to test the reliability of the data. Through specific analysis methods (canonical correlation analysis and structural equation modeling), to analyzes specific effects of corporate social responsibility actions to stakeholders.
1. Reliability and Validity analysis

This study uses the SPSS20.0 statistical analysis software to test the reliability and validity of the scale design. Prior to analysis, exploratory factor is firstly analyzed. KMO and Bartlett tests on samples show that the original dates are suitable for

Table 128.2 Impacts on stakeholders

	Factor	Index
The behaviors of the stakeholders	The behaviors of consumers B_1	Y_1 = the loss of the previous consumers
		Y_2 = enterprises have established customer feedback platform and often get customers' suggestions
		Y_3 = the old customers' recommend of new customers
		Y_4 = a satisfying increasing of new customers
	The avoidances of the competitors B_2	Y_5 = competitors have mimicked this enterprise
		Y_6 = competitors have avoid competition with this enterprise
	The continuous cooperation of partners B_3	Y_7 = has a good credit rating and credit amount
		Y_8 = attaches importance to the quality of exchanged information
		Y_9 = enterprises can get some preferences from their partners
	The supports from government/community B_4	Y_{10} = enterprises have get some preferential supports
		Y_{11} = enterprises' suggestions have been accepted by the government
		Y_{12} = enterprises have taken part in the discussion concerning livelihood
	The supports from media/public B_5	Y_{13} = enterprises can interact with media/public
		Y_{14} = enterprises have established the transmission emergency mechanism; and have employee to handle with the public opinion
		Y_{15} = the management of enterprises is transparent; and the enterprises have never experienced public crisis
		Y_{16} = the complaint problems have not been amplified

Resources Researches of SHI Jinluan, LIANG Lin and the interviews of experts

Table 128.3 Sample demographics

Programs	Classification	Frequency	Ratio
Educational degrees	PHD	29	7.20 %
	Graduates	170	42.10 %
	Postgraduates and below	188	46.50 %
	Technical secondary school and below	17	4.20 %
Occupations	Top managers	11	2.70 %
	Middle managers	171	42.30 %
	First-lien managers	98	24.30 %
	Senior technicians	24	5.90 %
	Middle technicians	70	17.30 %
	Junior technicians	30	7.40 %
Quality of enterprises	State-owned enterprises	193	47.80 %
	private enterprises,	142	35.10 %
	foreign-funded enterprises	14	3.50 %
	collective enterprises	17	4.20 %
	others	38	9.40 %
Numbers of employees	Below 500	175	43.30 %
	500–2000	119	29.50 %
	2001–5000	73	18.10 %
	5001–10000	9	2.20 %
	10001–50000	18	4.50 %
	Over 50000	10	2.50 %
History of enterprises (years)	Below 5	121	30.00 %
	6–15	148	36.60 %
	16–30	85	21.00 %
	31–50	16	4.00 %
	51	34	8.40 %

analysis. In this study, Cronbach's of corporate social responsibility, stakeholder are 0.805 and 0.598 respectively (In general exploratory study, if Cronbach's is >0.6, the test has a certain credibility, if Cronbach's $\alpha > 0.8$ the test is of high credibility). Therefore, the variable terms of corporate social responsibility has a very good internal consistency; variable terms of the stakeholders have a relatively good internal consistency.

2. Typical correlation analysis

Canonical correlation analysis is to analyze the relationship between two sets of multivariate data. Therefore, canonical correlation analysis can be used to discuss the

Table 128.4 Results of canonical correlation analysis of corporate social responsibility and stakeholders

	Consumers B_1	Competitors B_2	Partners/B_3	Government community B_4	Media/Public B_5
Charity A_1	0.211	0.149	0.214	0.828	0.72
Community responsibility A_2	0.053	0.091	−0.127	0.819	0.603
Environment responsibility A3	−0.006	0.103	−0.018	0.774	0.529

relationships between these two sets of variables as corporate social responsibility and stakeholder. According to the results of factor analysis, corporate social responsibility are made up of three variables, and stakeholders are made up of five variables. These two sets of variables are marked as A_1, A_2, A_3, and B_1, B_2, B_3, B_4, B_5. The variable value of the corporate social responsibility and stakeholders are obtained after the analysis of the factors. By SPSS20.0, after the processing of the questionnaire dates, the results are get as shown in Table 128.4.

According to the data analysis Table 128.4: the supports of Government/community, media/public have strong correlations with three social responsibilities, and correlation coefficients are 0.828, 0.819, 0.774 and 0.720, 0.603, 0.529, compared with other indexes, these indexes show more significant correlation. About other indexes, what actually consumers concern more are products and services provided by enterprises; and the correlation of enterprises' social responsibility behavior and consumers behavior is relatively less obvious. Competitors focus more on the in competition in the fields of core technology; thus the correlation of enterprises' social responsibility behavior and competitiveness is also small. Since cooperation partners mainly care whether enterprises can do business honestly, perform contract actively, and make information shared of real-time, so the correlation of enterprises' social responsibility behavior and partnership is also weak. Therefore, the enterprises have to firstly bear on social responsibilities to government/community and media/public to gain more policy supports and public supports.

We choose the factors affecting the corporate social responsibility actions (charity, community responsibility, environmental responsibility) to consumer behavior variables (the loyalty of the previous consumers, attraction of new consumers) to get canonical correlation analysis. Results are shown in Table 128.5.

Table 128.5 shows that the 4 canonical correlation coefficient is 0.430, 0.371, 0.223 and 0.167. From Canonical correlation coefficient matrix and significance test results, we can see the four test results of canonical correlation coefficients are significant.

Table 128.5 Canonical correlation coefficient and testing

Number	Canonical correlation coefficient	Wilk's testing	Chi-Square freedom	Degrees of probability	Significant
1	0.43	0.649	234.713	24	0
2	0.371	0.797	123.618	15	0
3	0.223	0.924	43.108	8	0
4	0.167	0.972	15.363	3	0.002

Table 128.6 Internal corporate social responsibility index of canonical correlation coefficients of standardized variables

	Standardized Canonical Coefficients for Set-1			
	1	2	3	4
F_1a_1	−0.002	0.152	−0.04	0.111
F_1a_2	−0.431	−0.39	−0.119	−0.632
F_1b_1	0.048	−0.843	0.157	−0.173
F_1b_2	−0.425	0.588	−0.042	−0.337
F_1c_1	−0.58	−0.076	0.677	0.461
F_1c_2	−0.275	−0.13	−0.798	0.563

Notes charity $\frac{F_1a_1}{F_1a_2}$, responsibility for community $\frac{F_1b_1}{F_1b_2}$, responsibility for environment $\frac{F_1c_1}{F_1c_2}$

According to Table 128.6:

Based on the first set of indexes of corporate social responsibility, the first canonical variants can be calculated as:

$$F_1(1) = -0.002F_1a_1 - 0.431F_1a_2 + 0.048F_1b_1 - 0.425F_1b_2 - 0.580F_1c_1 - 0.275F_1c_2. \tag{128.1}$$

Based on the second set of indexes of corporate social responsibility, the second canonical variants can be calculated as:

$$F_1(2) = 0.152F_1a_1 - 0.390F_1a_2 - 0.843F_1b_1 + 0.588F_1b_2 - 0.076F_1c_1 - 0.130F_1c_2. \tag{128.2}$$

Based on the third set of indexes of corporate social responsibility, the third canonical variants can be calculated as:

$$F_1(3) = -0.040F_1a_1 - 0.119F_1a_2 + 0.157F_1b_1 - 0.042F_1b_2 + 0.677F_1c_1 - 0.798F_1c_2(3-3). \tag{128.3}$$

Based on the fourth set of indexes of corporate social responsibility, the fourth canonical variants can be calculated as:

$$F_1(4) = 0.111F_1a_1 - 0.632F_1a_2 - 0.173F_1b_1 - 0.337F_1b_2 + 0.461F_1c_1 + 0.563F_1c_2. \quad (128.4)$$

From four typical variable expressions, we can see that there is not much difference of the coefficients of the four corporate social responsibility indexes, and if enterprises do more charities, more positively fulfill community responsibilities and environmental responsibilities, consumers are more willing or able to purchase the companies' products and services. In short, corporate social responsibility has great effect on consumer behavior.

(3) Structural equation model testing

Use EQS6.1 to test the assumption model.

There are three indexes are eventually used to measure enterprise social responsibility behavior: public charity, community responsibility and environmental responsibility. There are two indexes are used to measure consumers consumption behavior: the maintenance of old customers, and attraction of new customers. There are three indexes are used to measure cooperation of partners: credit status, and collaboration capacity. There are two indexes are used to measure avoidance of competition opponents the status in the whole industry, and comprehensive competitive advantages; There are two indexes are used to measure Government/Community policy supports: policy supports, and human-cultural environment; There are two indexes are used to measure the public/media opinion: the interaction of the media and public, and the supports from public and media.

This paper has checked the relationship between corporate social responsibility and consumer behaviors, partners, strategic cooperation, rivals avoidances, government/community supports, and public/media supports. And then a model is built. I is for latent variable customer consumption behavior, partner strategic cooperation, competitive rival avoidances, Government and regional policy, public and media supports; βI is for regression coefficients; ς is for the latent variable behavior of corporate social responsibility. The basic idea of building the model is:

$$\eta_i = \beta_0 + \sum \beta_i \zeta + \sum \beta_j \sum \zeta k \zeta k + 1 + \varepsilon. \quad (128.5)$$

Among them, the "$\zeta\ \zeta\ k\ k + 1$" represents the interactions between variables.

Figure 128.3 shows that the path coefficients of corporate social responsibility and consumer behavior, competitors' avoidance, partner, strategic cooperation, Government/community supports, and public/media/ supports are 0.38*, 0.09*, 0.28*, 0.33*, 0.37*. These results show that corporate social responsibility behaviors is positively related with consumer behavior, competitors avoidance, partner, strategic cooperation, Government/community supports, public/media supports. Therefore, the hypothesis of H1.1 H1.5 are further checked.

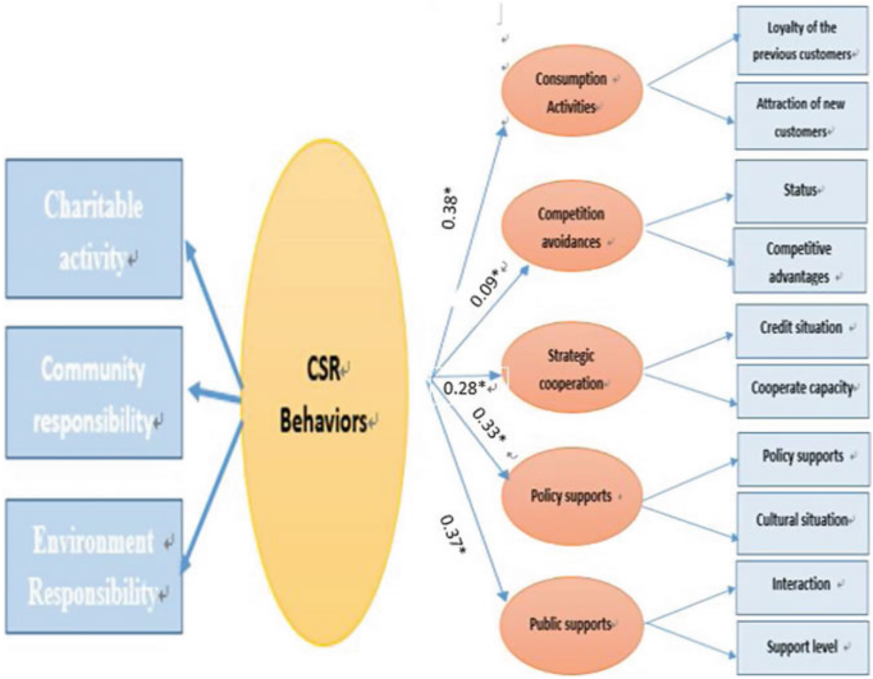


Fig. 128.3 The model of the relationship between corporate social responsibility and the stakeholders (* means P < 0.01)

128.4 Results and Discussion

128.4.1 Summary of Empirical Research Results

Table 128.7 shows the above research results:

128.4.2 The Discussions of the Results

(1) H1.1: Under the same conditions, corporate social responsibility is significantly positively correlate with consumer behavior. This assumption is valid. For consumers, the most important corporate social responsibility should be to provide qualified products and services to consumers. Bhattacharya [5] believed that consumers prefer to choose enterprises with positive images of corporate social responsibility. In addition, some scholars' have further linked the relationship of corporate social responsibility with consumer response to products directly. Lois et al. [13] argued that corporate

Table 128.7 Results of the examination of hypothesis

Number	Hypothesis	Result
1	H1.1: Under the same conditions, corporate social responsibility is significantly positively correlate with consumer behavior	valid
2	H1.2: Under the same conditions, corporate social responsibility is positively correlate with the competitors' avoidance	valid
3	H1.3: Under the same conditions, corporate social responsibility is significantly positively correlate with the continuing strategic cooperation partners	valid
4	H1.4: Under the same conditions, corporate social responsibility is significantly positively correlate with the supports of government/community	valid
5	H1.5: Under the same conditions, corporate social responsibility is significantly positively correlate with supports of public/media	valid

social responsibility can improve the value of products, and consumers' recognition of the social responsibility can be shown by the consumers' selecting.

(2) H1.2: Under the same conditions, corporate social responsibility is positively correlate with the competitors' avoidance. This assumption is valid, but the results show that the correlation is not significant. For the long-term development of themselves, enterprises and their competitors should try to maintain peaceful coexistence, try to avoid the vicious price war competitions, and try to maintain a healthy and fair competition environment. They should also try to learn from each other and pursue common development. In that respect, corporate social responsibility is not obviously correlated with competitors" avoidance.

(3) H1.3: Under the same conditions, corporate social responsibility is significantly positively correlate with the continuing strategic cooperation partners. This assumption is valid. Corporate social responsibility behaviors as public investments and environmental protection inputs, not only help the enterprises to win the good social images, but also improve brand values. If such values are accepted by their partners, their partnership will be deepened, and the both parts would prefer to maintain the sustainable development of strategic partnerships.

(4) H1.4: Under the same conditions, corporate social responsibility is significantly positively correlate with the supports of government/community. This assumption is valid. As social organizations, enterprises should assume a certain of responsibilities to social charity, social welfares and sustainable development of the environment. As an important part of the society, enterprises needs to survive in certain communities and environment. Thus enterprises take actions to improve community relations, promote the development of the society. These behaviors of enterprises can help them to win positive supports from government and community.

(5) H1.5: Under the same conditions, corporate social responsibility is significantly positively correlate with supports of public/media. This assumption is valid. Public/media tend to prefer enterprises with social responsibility, believing that these

businesses can provide beneficial impacts on social environment sustainable development. Thus they are more willingly to support these enterprises with corporate social responsibility.

128.5 Conclusion

Enterprises, as an ordered organization of production and management, provide the society and markets with various products and services. In the pursuit of profits, enterprises assume mandatorily economic and legal responsibilities, as well as selectively ethical, charitable responsibilities at the same time. Enterprises' behaviors are related to five main external stakeholders. There is a closed-loop feedback mechanism between corporate social responsibility and stakeholders. From a positive view, if the enterprises can bear some social responsibilities, they are more likely to promote the recognition and supports from the stakeholders, because if stakeholders actively fulfilling the social responsibility of enterprises and spontaneously increase the enterprise's satisfaction or support, will be an impetus for further active social responsibility of enterprises. From the reverse view, if stakeholders increased their supports to the enterprises due to their actively fulfilling the social responsibility, the enterprises are likely to be more actively assume social responsibilities.

References

1. Howard B (1953) Social responsibilities of the businessman. Harper & Row, NY
2. Penrose E (2007) Enterprise's growth theory. Shanghai People's Publishing House, Shanghai, pp 115–123
3. Carroll AB (1979) A three-dimensional conceptual model of corporate performance. Acad Manag Rev 4(4):497–505
4. Clarkson ME (1995) A stakeholder framework for analyzing and evaluating corporate social performance. Acad Manag Rev 20(1):92–117
5. Bhattacharya CB, Sen S (2003) Consumer-company identification: a framework for understanding consumers' relationships with companies. J Mark 67(2):76–88
6. Davis K (1960) Can business afford to ignore social responsibilities? Calif Manag Rev 2(3):70–76
7. Frederick WC (1994) From CSR1 to CSR2 the maturing of business-and-society thought. Bus Soc 33(2):150–164
8. Friedman M (1972) Social responsibility of business. In: Economist's protest, columns in political economy
9. Freeman M (2006) Strategic management: a stakeholder approach. Shanghai Translation Publishing House, Shanghai
10. McGuire JB, Sundgren A, Schneeweis T (1988) Corporate social responsibility and firm financial performance. Acad Manag J 31(4):854–872
11. Kou X, Zhao C, Sun Y (2014) Rearch on the influence of corporate social responsibility. Competitiveness 15:179–181
12. Zhu F, Tu G, He L (2014) Social costs: theoretical explanation and practical considerations. Sichuan Univ J (Philosophy and Social Science Edition) 5:92–101

13. Mohr LA, Webb DJ (2005) The effects of corporate social responsibility and price on consumer responses. J Consum Aff 39(1):121–147
14. Li J (2009) From the perspective of the resouces to evaluate corporate social responsibility and firm financial performance. Zhejiang Gongshang University, Zhejiang
15. Mitchell RK, Agle BR, Wood DJ (1997) Toward a theory of stakeholder identification and salience: defining the principle of who and what really counts. Acad Manag Rev 22(4):853–886
16. Xie P, Zhou Z (2009) CSR in china and consumer purchase intent: an empirical study. Nankai Bus Rev 1:64–70
17. Research Center of the Shanghai Stock Exchange (2007) Stakeholders and corporate social responsibility. Fudan University Press, Shanghai

Chapter 129
An Ecological Carrying Capacity Analysis of the Low-Carbon Economic Development of Downtown Leshan

Zhiyi Meng and Xiaotong Jian

Abstract Ecological footprint methodology is to quantitatively evaluate whether the development of a specific zone is within the range of its ecological carrying capacity by measuring the gap between the human ecological footprint and ecological carrying capacity, so as to provide a scientific basis for sustainable development of the assessed object. Analyzing the carrying capacity of the current environmental resources in downtown Leshan from the perspective of ecological footprint methodology, the paper concludes with the current conditions and features of the ecological supply and its demand, which provides an ecological and environmental basis for the urban planning of Leshan. Moreover, comparing Leshan with its neighboring areas as well as some more developed zones, the paper also finds out some specific approaches to optimizing its ecological carrying capacity.

Keywords Ecological footprint · Ecological supply · Ecological carrying capacity · Sustainable

129.1 Introduction

Eco-environmental protection is not only a great performance, but also a giant project, which is reactive power in the contemporary era and the benefit of future generation [10]. To made unremitting efforts to develop the ecological environmental protection is a succession and development of industriousness, an important part of maintaining sustainable development of economy, society and environment and are the base for fulfilling the concept of scientific development, building harmonious society and establishing economical society [3]. The ecological carrying capacity of a specific zone is the basis and premise of achieving regional economic development, society and environmental coordinated development, which provides an important basis for

Z. Meng (✉) · X. Jian
Business College, Sichuan Agricultural University, Dujiangyan 611800,
People's Republic of China
e-mail: zhiyimengscu@sina.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_129

something, whether there is coordination between intense exploitation of economic and environmental carrying capacity [2]. Hence, in order to implement sustainable developmental strategy comprehensively, carry out the basic state policies of environmental protection, and strengthen outcomes of ecological construction [4], it is necessary that carrying capacity of eco-environments is evaluated and predicted effectively.

In recent years, in the light of the Scientific Outlook on Development, we can see a significant economic growth in downtown Leshan. For example, it contributes to businesses growth, urban sprawling and population growth. It is, however, inescapable that it is based on the utilization of resources in the ecological environment in downtown Leshan. At the same time, Leshan Giant Buddha which is the world heritage is located in middle district of Leshan [9]. It is obvious that it is able to increase the development of reliance on eco-environments. Therefore, when it comes to the future plan of the development of Leshan, We must also have a clear understanding of the current situation of ecological carrying capacity and calculate the ecological carrying capacity spatial, in order to offer a guidance of making a sustainable development plan in the future in downtown Leshan [6].

129.2 Modeling

At the present, the ecological footprint approach mainly includes synthetic method, component method, input-output analysis and so on. The synthetic method has been raised since the middle of 1990s. It applies to ecological footprint research at the region level and all over the world. On a national level, it concentrates on comparative static analysis; at a regional scale, synthetic method is mainly adopted in calculation of ecological footprint at present. When we calculate the ecosystem carrying capacity, we usually use the national productivity of land average data.

129.2.1 Model Description

Considering relationships among human and its development and ecological condition from a new prospective, ecological footprint methodology is a biophysical assessment method. Ecological footprint methodology is suggested to give an accounting of global, national, regional, and families and individuals of natural capital utilization for a concise framework, which is necessary to produce the resources and energy consumed in a region by tailing after region energy and resource consumption. Ecological footprint methodology is to quantitatively evaluate whether the development of a specific zone is within the range of its ecological carrying capacity by measuring the gap between the human ecological footprint and ecological carrying capacity, so as to provide a scientific basis for sustainable development of the assessed object.

In the process of calculating the carrying capacity of ecological, equivalence factors and yield factors variable is going to be frequently used [1]. The method assumes that the carrying capacity of ecological provided by two different kinds of can be substituted because of the different productivity in ecosystems. In this way, adopting equivalence factors can quantify the area ecosystems. It can be converted into area ecosystems with ecological average productivity. Thanks to yield factors, the productivity from different countries and regions can be expressed as the area of the ecological system with the global average ecological productivity.

Ecological Footprint Calculation is based on the following six assumptions [9]:

(1) It is possible that we can track most human society consumes resource and waste.
(2) Most of these resource and waste flow can be measured in accordance with the essential biological productive area of support for these flows.
(3) Various types of land can be converted into standard ha- Global hectares. one global hectares of biological production capacity is equal to the average productivity of the global land.
(4) The land use is repellent, so it can be summed up to be one of the human consumption demand.
(5) The supply of natural ecological services can also be expressed in the biological production space with the global hectares.
(6) Ecological footprint can exceed the biological carrying capacity.

129.2.2 Index System

Footprint on biological index system is a unified whole, the selection of the index and the construction of the system should be able to reflect the connotation of sustainable development. It is generally to follow the following principles [5, 7, 8, 11]:

(1) Conciseness and scientific. Ecological occupancy index system must be built on the basis of science, which is clear and have a wide coverage. It can objectively reflect the regional resources and ecological sustainable development.
(2) Integrity and completeness. As a comprehensive indicator of the sustainable development of a region, ecological occupancy should reflect the main features and conditions of the evaluation from all angles.
(3) Dynamic and stability. Ecological occupancy index system should maintain the relative stability for a certain period of time. However, with the development of region, index system should be adjusted accordingly to adapt to changes in time and space of sensitivity. It can truly reflect a future development trend.

Based on the basic principle, shown in Fig. 129.1, a indicator of ecological occupation will be built.

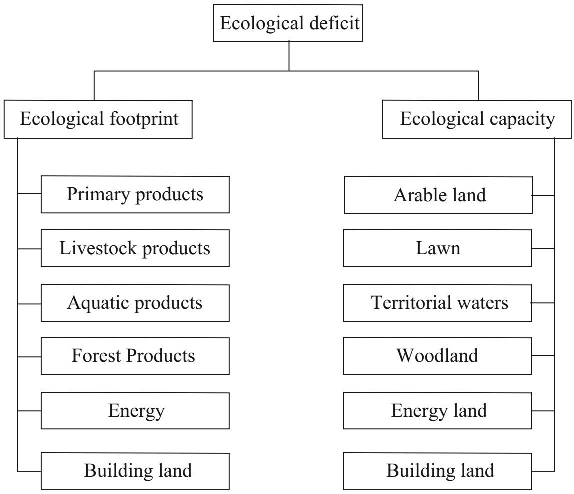


Fig. 129.1 The indicator system of ecological occupation

129.2.3 Data Source

The calculation data by model come from the urban statistical yearbook and relevant departments. After sorting the main life consumption and production consumption data in 2008, we are able to get available data.

129.2.4 The System of Equations

At present the distribution of biological resource usage is used more FAO in 1999 about biological resources of the world's average production so that the calculation results can be compared. It will provide the main consumption into consumer goods of biological production area formula is:

$$A_i = \frac{X_i}{\overline{Y}}, \tag{129.1}$$

where i is the type of consumer goods, A_i is the ith per capital biological-production areas which is converted by article of consumption, X_i is the ith per capital consumer, $\overline{Y}$ is the account average output of biology in the world.

Secondly, we need to calculate energy occupation. The calculation of energy is that the major energy consumer such as coal, petroleum, gas and hydropower may be changed into standard coal. The energy consumer may be changed into fossil fuel. The computational formula of the land area is:

$$X_i = \frac{A_i}{\overline{Y}}, \tag{129.2}$$

where X_i is the ith per capital ecological occupation, A_i is the ith per capital consumer, $\overline{Y}$ is the ith per capital energy average output rate.

All kinds of biology resources and the consumption of energy constitute gross ecological occupation. Formula is:

$$EF = N \times ef = N \times \sum(aa_i) = N \times \sum\left(\frac{C_i}{P_i}\right), \tag{129.3}$$

where i is the type of consumer goods and input, C_i is the ith per capital consumer, p_i is the ith average input ability of consumer, aa_i is the ith biological production area of the exchange of goods, N is the total population, ef is the ecological footprint per capital, EF is the total ecological footprint.

Judging from the bio-productive land types, the resource environmental bearing capacity (ecosystem carrying capacity) can be calculated in the circumstances, Formula is:

$$ec = a_i \times r_i \times y_i, i = 1, 2, 3, \ldots, \tag{129.4}$$

where ec is the ecological capability per capital, a_i is the bio-productive areas per capital, r_i is the balance factor and y_i is the yield factor.

The regional ecosystem's carrying capacity formula is:

$$EC = N \times (ec), \tag{129.5}$$

where EC is the regional ecosystem's carrying capacity and N is the total population.

129.3 Comprehensive Evaluation

Through the urban area in 2008 data collation, we can analysis whether ecological occupancy and ecological supply in urban areas is in a state of sustainable development.

129.3.1 The Actual Calculation

Several biological resources occupy the calculation results are shown in Table 129.1.

The results of calculation of the energy occupancy in the city are shown in Table 129.2.

The city center of ecological footprint demand can be seen in Table 129.3.

Table 129.1 Calculation results of biological resources

Project classification	Consumption of city central district (t)	Average global output (kg × hm^{-2})	Total ecological occupancy (hm^{-2})	Ecological footprint per capital ($hm^{-2} \times cap^{-1}$)	Biological production
Agriculture products					
Rice	136086	2744	49594.02332	0.085509591	Cultivated land
Wheat	2337	2744	851.6763848	0.001468453	Cultivated land
Corn	10414.5	2744	3795.37172	0.006543947	Cultivated land
Peas and beans	3244.5	1856	1748.114224	0.003014084	Cultivated land
Root crops	16057.5	12067	1330.695285	0.002294373	Cultivated land
Oil	12690	1856	6837.284483	0.011788787	Cultivated land
Tobacco	120	1548	77.51937984	0.000133658	Cultivated land
Silkworm	769.5	1000	769.5	0.001326765	Cultivated land
Tea	499.5	1182	422.5888325	0.000728624	Cultivated land
Vegetables	309390	18000	17188.33333	0.029635977	Cultivated land
Sugar	1726.5	65204	26.47843691	0.000045654	Cultivated land
Livestock productivity yield					
Pork	48430.5	457	105974.8359	0.182720905	Grassland
Beef	1050	33	31818.18182	0.054860637	Grassland
Mutton	172.5	33	5227.272727	0.009012819	Grassland
Poultry	23046	457	50428.88403	0.08694905	Grassland
Eggs	35905.5	400	89763.75	0.154769889	Grassland
Aquatic products	16600	29	572413.7931	0.986950962	Grassland
Forest products production					
Nuts	177	3000	59	0.000101727	Woodland
Fruit	35934	3000	11978	0.020652365	Woodland

Table 129.2 The main energy consumption in the city and the per capital ecological occupancy

Fuel type	Consumption of city central district (ton)	Consumption per head ($10^3 \times$ cap^{-1})	Global average energy occupancy (GJ $\times$ hm^{-2})	Conversion factor (GJ $\times$ 103 kg^{-1})	Per capital ecological footprint	Occupancy type
Raw coal	1038913.05	37.49875996	55	20.934	0.681795636	Fossil fuel
Gasoline	172214.95	12.80487565	93	43.124	0.137686835	Fossil fuel
Natural gas	44441.7	29.8312683	93	389.31	0.320766326	Fossil fuel
Power	137243.4	2.801745323	1000	11.84	0.002801745	Construction land

Table 129.3 Ecological footprint demand

Ecological occupancy demand			
Type (hm$^2 \times$ cap^{-1})	Demand area (hm$^2 \times$cap^{-1})	Equivalent factor	Ecological occupancy
Cultivated land	0.142489914	2.8	0.398971759
Woodland	0.020754092	1.1	0.022829501
Grassland	0.4883133	0.5	0.24415665
Waters	0.986950962	0.2	0.197390192
Construction land	0.002801745	2.8	0.007844887
Fossil fuel	1.478066007	1.1	1.625872608
Total demand area			2.497065598

129.3.2 Conclusion Analysis

(1) Occupancy Ratio Analysis

According to Tables 129.1 and 129.2, we can calculate that Leshan the major living consumption and energy consumption ecological occupancy for 2.50 hm$^2 \times$ cap^{-1} in 2008. According to Table 129.3, the proportion of fossil fuels in central area is very large, accounting for more than 60 %.The proportion of water is only 20 %, which shows the proportion of ecological footprint's unbalance.

(2) Supply and Demand Balance Analysis

Through the comparison between Tables 129.3 and 129.4, we can see that the per capital account for hm$^2 \times$ cap^{-1} in 2008 in downtown Leshan, the per capital ecological consist of 2.06 hm$^2 \times$ cap^{-1} and 2 ratio of 1.3. It shows that City Central Ecological occupation is a little large. However, it can meet the basic needs of the occupation thanks to the strength of the city district ecological supply capacity, especially cultivated land has played a pillar role to. It should be noted that the city in 2008. Only thing to note here is that the total supply and demand has appeared the characteristics of the ecological deficit, that is to say, there is a imbalance. Therefore, we should pay more attention on this in the future development.

Table 129.4 Ecological occupancy supply in Leshan

Per capital ecological footprint supply					
Type	Total area	Supply area ($hm^2 \times cap^{-1}$)	Equivalent factor	Yield factor	Ecological carrying capacity ($hm^2 \times cap^{-1}$)
Cultivated land	284925	0.491265246	2.8	1.66	2.283400864
Woodland	27819.8	0.047966661	1.1	0.91	0.048014628
Grassland	29163	0.050282595	0.5	0.19	0.004776847
Waters	1906.7	0.003287516	0.2	1	0.000657503
Construction land	261.27	0.000450479	2.8	1.66	0.002093829
Total supply area	–	–	–	–	2.33894367
Bio diversity conservation area	–	–	–	–	0.28067324
Total available space	–	–	–	–	2.05827043

Table 129.5 Comparison of ecological footprint, ecological carrying capacity

Type	City district	Sichuan province	Western 12 provinces	Eastern region	All the country	Global
Per capital ecological footprint	2.497065598	0.951	1.172	1.379	1.326	2.8
Per capital ecological supply	2.05827043	0.385	0.718	0.513	0.618	2
Per capital ecological deficit	−0.438795168	−0.566	−0.454	−0.843	−0.645	−0.8
Million GDP ecological footprint	1.335329197	2.141	2.721	1.306	2.038	–

(3) The Comparative Analysis

Comparison of ecological footprint, ecological carrying capacity and ecological footprint of 10000 yuan GDP in the city and other regions can be seen in Table 129.5.

In Table 129.5 we can see the per capital ecological footprint in Leshan is nearly 3 times than that in Sichuan province and is 2 times than the western, Eastern and the Whole country, while the ecological supply is about 7 times than that in Sichuan province, is about 3 times than that in the East and West. It is based on the above two point, the city's huge ecological footprint can be barely supported, so that the ecological deficit are in a relatively low level.

Million GDP ecological footprint reflects the use efficiency of regional resources. We can use the total ecological footprint and the GDP value of the year, the ecological footprint of GDP was 1.36 per year in 2008. The resource utilization efficiency was similar with that of the eastern region, which was better than other parts of Sichuan province and the West.

129.4 Policy Suggestion

Based on the above results, we are trying to find out the cause of the "ecological deficit", and analysis the ecological problems in the economic development of the city in the future. Moreover, we would like to put forward countermeasures. We hope to lay a foundation for the urban construction of low carbon demonstration pilot area and the harmonious and sustainable development of the city in the future.

129.4.1 Possible Reasons

(1) The large consumption of Fossil energy account for the majority of the total ecological footprint. This is closely related to the rapid development of economy in the city as well as a large amount of the consumption of fossil energy. It is based on energy structure of coal-dominating. With the expediting of urbanization and industrialization, coal resources consumption are increasingly growing.
(2) There exists ecological space in downtown Leshan the problems of single supply type and limited total size. In the downtown district, ecological space types are mainly cultivated land, moreover, grassland, water area, the supply of land for construction space is very limited.
(3) Being an ecological fragile, the area of soil erosion of a thousand mountain areas cover 348.83 sq $\times$ km, which accounts for 41.72 % of the land area. The average soil erosion loss reaches 2646.43 ton/km^2. The annual average amount of soil erosion is 92.29 m tones.

129.4.2 Feasible Solutions

(1) We must pursue comprehensive, balanced and sustainable ecological development, which contributes to the industrialize and ecologicalize as well as economic and environmental coordinative development. Take full account of the regional society, economic and resources as well as environmental coordinated development in order to promote the development of urban and rural areas harmony between man and nature, so as to achieve economic, social and environmental benefits of the "win-win".

(2) Improving the ecological carrying capacity

Firstly, it is necessary to strengthen the investment in ecological environment construction and management. Secondly, in no cases, should we neglect the importance of implementing Natural Forest Conservation Programme Improve and increase the artificial forest area. Thirdly, It is essential to increase production output of natural resources per unit area, use the existing stock of resources efficiently. Last but not least, we should focus on human resource development and technology investment.

① Carrying out the construction of agricultural modernization. To begin with, it is necessary to strengthen basic farmland construction, adjust industrial structure as well as promote the transformation from traditional agriculture to modern agriculture. Still, we should implement protective farming strictly and make control of non-agricultural occupation of farmland. What is more, it is important for us to establish compensation mechanism for farmland, increase land consolidation efforts to ensure that the basic farmland is not reduced and invariably use as well as invariant mass in order to lay a foundation for agricultural modernization.

② Promoting ecological restoration. It is essential to promote natural forest protection, forest, soil erosion, field protection, land remediation and other ecological restoration planning,improve the implementation of green channel along the Yangtze River protection forest, landscape greening, habitat forest and other projects. In addition, there is no deny that we would like to build a system including green landscape, large green, green corridor, and green space to improve the ecological carrying capacity.

(3) Reduce the ecological footprint

① setting up resource economizing type society. It is necessary to establish a resource-saving society production and consumption system in order to control population growth as well as reasonable planning and urban and rural development, and reduce the occupation demand and accelerate industrial restructuring, What is more, we should pay more attention to promote industrial upgrading and transformation as well as adhere to the line of technological content, good economic benefits, low resource consumption, environmental pollution and human resource advantages.

② Popularization of new energy use. City center can use solar energy industry to develop solar energy industry, we can use both new alternative energy and agricultural resources. Biogas fermentation raw material is adequate. It is suitable for developing a broad region of methane and improving the rural biogas farmers' popularization rate. Furthermore, I would like to talk about the fact that the importance of accelerating the construction of urban living sewage and reliving sewage treatment.

③ Waste disposal On the foundation of garbage classification, we can sort garbage into plastics, paper, cloth and other organic matter, in addition, we can also sort garbage into scrap iron and steel, copper, aluminum and other metals, glass, nonferrous metals which can be composted, other screening and other inorganic compounds. On the one hand, waste paper recycling can be used as reworked plastics fee. On the other hand, it can be also changed into fuel oil or petroleum gas to use as energy.

④ Strengthen the supervision on the ecological environment of resource development activities and construction projects. To control unreasonable resource development as one of the priority we should strengthen the protection of water, land, forests and other natural resources.

129.5 Conclusion

As we all know, ecological footprint methodology is to quantitatively evaluate whether the development of a specific zone is within the range of its ecological carrying capacity by measuring the gap between the human ecological footprint and ecological carrying capacity, so as to provide a scientific basis for sustainable development of the assessed object.

In this study, analyzing the carrying capacity of the current environmental resources in downtown Leshan from the perspective of ecological footprint methodology, the paper concludes with the current conditions and features of the ecological supply and its demand, which provides an ecological and environmental basis for the urban planning of Leshan. Besides, comparing Leshan with its neighboring areas as well as some more developed zones, the paper also finds out some specific approaches to optimizing its ecological carrying capacity.

References

1. Byron C, Link J et al (2011) Calculating ecological carrying capacity of shellfish aquaculture using mass-balance modeling: Narragansett Bay, Rhode Island. Ecol Model 222(10):1743–1755
2. Chen Y, Ye Z, Zheng X (2010) On harmonious development between regional floating population and social economy. Contemp Econ Manag
3. Chu C, Meng H (2006) Ecology migration and sustainable development of economy in inner mongolia autonomous region. Res Agric Modernization 2:005
4. Guo X (2003) Essects and solutions of market subject's craying for profits on sustainable development strategy. J Nanjing Inst Technol
5. Jones EM, Doblin MA et al (2015) Assessing and evaluating the ocean-colour footprint of a regional observing system. J Mar Syst 143:49–61
6. Liu D, Feng Z et al (2011) Spatial patterns of ecological carrying capacity supply-demand balance in China at county level. J Geogr Sci 21(5):833–844
7. Naval J, Farrés J (2010) Systems biology footprint. Nutrafoods 9(3):31–35
8. Wei H, Hu E (2011) Dynamic analysis of ecological footprint of biological resource: a case study of the "two circles" in Hubei province. China Popul Resour Environ 21:167–174 (in Chinese)
9. Xu Z, Zhang ZQ et al (2003) Ecological footprint calculation and development capacity analysis of China in 1999. Chin J Appl Ecol 14(2):280–285
10. Zheng M (2011) Resources and eco-environmental protection of salt lakes in China. Environ Earth Sci 64(6):1537–1546
11. Zhou P, Liu G (2009) The change in values for ecological footprint indices following land-use change in a loess plateau watershed in China. Environ Earth Sci 59(3):529–536

Chapter 130
An Analysis of Rumor Propagation Based on Event Ambiguity

Yi Zhang

Abstract In this paper, a new rumor spreading model considering hesitating mechanism and the event ambiguity triggering rumors is proposed. On the basis of prior studies, we add a function reflecting the ambiguity of event to SEIR model. Then, several rumor spreading model simulations are conducted with different parameters on both random networks and BA networks. The simulation results indicate that a rumor spreads faster and more broadly when *c* is smaller. This shows that if events are ambiguous over a longer time, rumor spreading appears to be more effective. And rumor faster in a BA network than in a random network, but spreading scale on random network is bigger than that on BA network. Simulation results also show that the bigger transformation probability that lurkers become spreaders,the bigger the rumors influence, but the number of stifler is almost same when the spreading process terminate. In addition, the bigger forgetting rate, when other parameters are fixed, the smaller the peak value of spreader and the final size of the stiflers stifler.

Keywords Rumor spreading · Hesitating mechanism · Ambiguity · Network

130.1 Introduction

In our real life, the outbreak of public emergencies often with rumors of a large number of breeding and spread rapidly. As an important form of social communication, rumor also can be perceived as the contagion of thoughts whose authenticity cannot be judged, which has a great influence on peoples life. Due to ambiguity of events, Rumors helps people to cope with and adapt to ambiguous crisis situations, and to relieve emotional tension. Therefore, the ambiguity of the evidence pertaining to the events plays an important role in the spread of rumors. For example, a latest

Y. Zhang (✉)
Department of Mathematics, Yibin University, Yibin 644007, People's Republic of China
e-mail: zhangyi_110_110@163.com

Y. Zhang
Business School, Sichuan University, Chengdu 610064, People's Republic of China

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_130

shocking news, a Malaysian airplane (MH370) with 239 passengers just disappeared after its departure from the airport. Then rumors about this disappearances had spread fast around the world. When governments were intensifying their efforts to search for the jet, one after another rumors are born. The reason is the fact of this event keeps ambiguous. In addition, with the emergence of online social networks, rumors no longer spread from mouth to mouth in a small area, but rumors spread among stranger, different areas, and different countries, which cause the spreading of rumors is faster and wider than ever before. This sustained and rapid spreading can shape public opinion [10], and lead to social panic and instability easily [12, 17].

Previously, many researchers have focused on rumor spreading models and did a lot of valuable research. In the early stage, Daley and Kendall [3] constructed a mathematical model for the spreading of rumors from the point of view of mathematical epidemiology. Sudbury [12] studied the dynamic behavior of rumor spreading using the SIR model of epidemic dynamics. Then some scholars studied rumor spreading models on small-world networks and on scale-free networks [7, 17]. Based on these research, many researchers proposed rumor spreading models, most of which are variant of SIR model [8, 15, 18]. With the development of network technology, many novel models appeared inspired by empirical discoveries about network topology [5, 8, 11, 14]. In addition, A model based on the physical theory is proposed [4]. Moreover, scientists started to consider the specific features of rumor spreading in their models. While they did not consider content of rumor. In 1947, Allport and Postman gave a rumor formula: R(rumor) = I(important) × A(ambiguous) [1] which shows the relations between the generation of rumor and the importance and ambiguity of the event. Some works also shows that rumor content plays an important role in the propagation of rumor [2, 9, 13].

However, if the existing spreading models are directly applied to the rumor spreading process of complex social networks, the following problems will still exist. Firstly, the lurker state in rumor spreading process is similar to exposed state in epidemic spreading process, so it should be considered in the model. People in the state of spreader start to hesitate about the content of rumors and become confused again when the gossips of the emergencies fill all the places. Secondly, event ambiguity has been shown that it has a significant impact on the spread of rumor in many researches of sociologists who highlighted the relationship between the intensity of a rumor, the ambiguity of the event there has not yet been a rumor spreading model which considers the event features which cause the triggering of rumors as a function of time. Xia et al. [16] considered fuzziness of rumor in the model, but the parameter of fuzziness of rumor as a constant. Obviously, the extend of event fuzziness is changing in time.

The rest of the paper is organized as follows. In Sect. 130.2, We state the problem of rumors spreading and establish the model. Then we give the reasons why we establish such a model and explain the meaning of the model. In Sect. 130.3, the dynamic analysis of the model conducted. In Sect. 130.4, we draw simulations about the model in two network: random networks and BA networks. We conduct the sensitivity analysis of parameters in the model. Finally we conclude this paper, and describe the main conclusion, and explain the causes of this conclusion, and compare the results to others'.

130.2 Model

Consider a network with N nodes and E links representing the individuals and their interactions. At each time step, each individual is in one of four states:

(1) the unaware—this individual has not yet heard the rumor.
(2) the lurkers—this individual knows the rumor, but is not willing to spread it because they require an active effort to discern the truth or falseness of the rumor.
(3) the spreaders—this individual knows this rumor, and transmits it to all their contacts.
(4) the stiflers—this individual neither trusts the rumor nor transmits it.

Denote $S(t)$, $E(t)$, $I(t)$, $R(t)$ as the density of the unaware, lurkers, spreaders, stiflers at time t, $S(t) + E(t) + I(t) + R(t) = 1$. The process of SEIR rumor spreading is shown in Fig. 130.1.

This function $p(t)$ is extent of the event ambiguity that a function of time t. The extent of the event ambiguity ambiguous is normalized in [0,1], with 1 representing high ambiguity, and 0 representing no ambiguity. Thus, the more ambiguous an event, the greater $p(t)$. Generally speaking, as time passes, the facts of the event become more clear, that is, $p(t)$ decrease from big to small with the time t. In light of the above analysis, the probability at time t can be denoted as

$$p(t) = e^{-ct}, 0 < c \leq 1, t \geq 1,$$

where c is the parameter to reflect the clear speed of the rumor related event. A larger c indicates that the event becomes clearer faster. Figure 130.2 shows the probability as a function of t, given a different c. For example, when $c = 0.01$, the event becomes clear at time 400, and when $c = 0.005$, the event becomes clear at time 1000. When c tends to zero, the clear speed of the event slows down.

The forgetting rate is α $(0 < \alpha \leq 1)$. The event ambiguity $p(t)$ conforms to the human mind that people like to explore the truth, so the spreader will revert to the

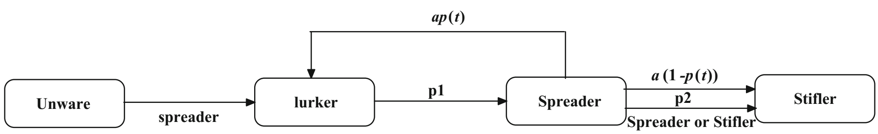


Fig. 130.1 Structure of rumor spreading process

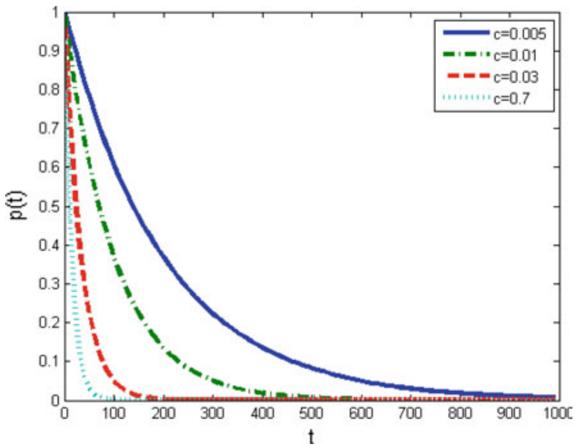


Fig. 130.2 Extent of the event ambiguity as a function of t

lurker with probability $\alpha p(t)$ which is proportional to extent of ambiguity $p(t)$. If the event is clear, the spreader will forget the rumor and become a stifler at a rate $\alpha(1 - p(t))$ which is proportional to clarity $1 - p(t)$. The assumptions above are based on the rumor spreading mechanism in complex social network, the hesitating mechanism and the ambiguity of the event triggering rumors itself in real life.

As shown in Fig. 130.1, the rumor spreading rules can be summarized as follows:

(1) When a spreader contacts an unaware, the unaware becomes a lurker at the rate of 1, The contact probability k is decided by the specific network topology. Therefore, the reduced speed of the unaware $dS(t)/dt$ is proportional to the number of the unaware $S(t)$ and spreaders $I(t)$, so we get the differential equation:

$$\frac{dS(t)}{dt} = -kS(t)I(t). \tag{130.1}$$

(2) We assume that transfer probability p_1 from a lurker to a spreader which depends on cognition. Some unaware have strong knowledge structures and logical reasoning abilities, so they may have little interest in rumors, thus the probability p_1 is small. From the structure of rumor spreading process, the exposed users will trigger a second rumor spreading, so the spreader will revert to the lurker with probability $\alpha p(t)$ which is proportional to extent of ambiguity $p(t)$. Because an unaware becomes a lurker with a probability 1 when an unaware contacts a spreader, the increased speed of the lurkers $dE(t)/dt$ is equal to

$$\frac{dE(t)}{dt} = kS(t)I(t) + \alpha p(t)I(t) - p_1 E(t). \tag{130.2}$$

(3) When two spreaders contact each other, both may find the two pieces of information inconsistent, so they stop the spread. When a spreader contacts a stifler, the spreader tries to stop the spread, as the stifler shows no interest in the rumor or

denies its veracity. We suppose that the above cases occur at the same probability p_2. If the rumor is clear and concise, from above analysis, the spreader will forget the rumor and become a stifler at a rate $\alpha(1-p(t))$. Therefore, the reduced speed of the spreaders $dI(t)/dt$ is proportional to the number of $I(t)$ and $R(t)+I(t)$, Additionally, a spreader becomes a stifler at the rate of $\alpha(1-p(t))$, so we have

$$\frac{dI(t)}{dt}=p_1E(t)-kp_2I(t)(I(t)+R(t))-\alpha I(t). \tag{130.3}$$

(4) The increasing speed of the stiflers $dR(t)/dt$ is proportional to the number of existing $I(t)$ and a spreader becomes a stifler at the rate of $\alpha(1-p(t))$ from Eq. (130.3), so we get

$$\frac{dR(t)}{dt}=kp_2I(t)(I(t)+R(t))+\alpha(1-p(t))I(t). \tag{130.4}$$

Based on the previous discussion, the model is described using the following system of differential equations:

$$\begin{cases} \frac{dS(t)}{dt}=-kS(t)I(t) \\ \frac{dE(t)}{dt}=kS(t)I(t)+\alpha p(t)I(t)-p_1E(t) \\ \frac{dI(t)}{dt}=p_1E(t)-kp_2I(t)(I(t)+R(t))-\alpha I(t) \\ \frac{dR(t)}{dt}=kp_2I(t)(I(t)+R(t))+\alpha(1-p(t))I(t) \\ S(0)=S_0,\ E(0)=0,\ I(0)=1-S_0>0,\ R(0)=0. \end{cases} \tag{130.5}$$

130.3 Steady-State Analysis of Model

Since the unaware $(S(t))$, the lurker $(E(t))$, the spreader $(I(t))$ and the stifler $(R(t))$ satisfies the equation $S(t)+E(t)+I(t)+R(t)=1$, Substituting $I(t)+R(t)=1-S(t)-E(t)$ into differential Eq. (130.3), because the differential Eqs. (130.1)–(130.3) are not related to the $R(t)$, we only consider the following three equations.

$$\begin{cases} \frac{dS(t)}{dt}=-kS(t)I(t) \\ \frac{dE(t)}{dt}=kS(t)I(t)-\alpha p(t)I(t)-p_1E(t) \\ \frac{dI(t)}{dt}=p_1E(t)-kp_2I(t)(1-S(t)-E(t))-\alpha I(t) \\ S(0)=S_0,\ E(0)=0,\ I(0)=1-S_0>0,\ R(0)=0. \end{cases} \tag{130.6}$$

From differential equations theory, system (130.5) and (130.6) are homogeneous, which means that analyzing the properties of system (130.6) is equal to analyzing the properties of system (130.5). This model is a nonautonomous differential dynamic system, the general form of which is

$$\begin{cases} \frac{d\mathbf{x}}{dt} = \mathbf{f}(t, \mathbf{x}) \\ \mathbf{f}(t, 0) = 0, x \in R^n. \end{cases} \tag{130.7}$$

Before the steady state analysis, some definitions and the required theorem are introduced. Suppose that $I = [t_0, +\infty]$, $U = \{\mathbf{x} \mid \ \| \mathbf{x} \| \leq h\}$, and $V(t, \mathbf{x})$ is a continuous differentiable function defined in $I \times U$. $W(\mathbf{x})$ is a continuous differentiable function defined in U.

Definition 130.1 ([6]) If $W(\mathbf{x})$ is a positive (negative) definite function, such that $V(t, \mathbf{x}) \geq W(\mathbf{x})(V(t, \mathbf{x}) \leq -W(\mathbf{x})$ is true in $I \times U$, and $V(t, \mathbf{0}) = 0$, $V(t, \mathbf{x})$ is called a positive(negative) definite function in $I \times U$. If $V(t, \mathbf{x}) \geq 0(V(t, \mathbf{x}) \leq 0)$, $V(t, \mathbf{x})$ is called a positive(negative) semi-definite function.

Definition 130.2 ([6]) If $W_1(\mathbf{x})$ is a positive(negative) definite function, such that $\mid V(t, \mathbf{x}) \mid \leq W_1(\mathbf{x})$, it is called $V(t, \mathbf{x})$ and has an infinitesimally small upper bound. If $W_2(\mathbf{x})$ is an infinite positive definite function, such that $V(t, \mathbf{x}) \geq W_2(\mathbf{x})$, it is called $V(t, \mathbf{x})$ and has an infinite lower bound.

Theorem 130.1 ([6]) *Suppose that $V(t, \boldsymbol{x})$ is a positive definite function in $I \times R^n$, which has an infinitesimally small upper bound and an infinite lower bound, and $\dot{V}(t, \boldsymbol{x})$ is a negative semi-definite, so the zero solutions for system (130.7) are global uniformly asymptotically stable.*

Theorem 130.2 *P^*=(S^*, 0, 0) (0$\leq$ S^* $<$ 1)is the equilibrium of the system (130.6).*

Proof Let the right side of each of the differential equations be equal to zero in the system (130.6) which gives the equation

$$-kS(t)I(t) = 0, \tag{130.8}$$

$$kS(t)I(t) + \alpha p(t)I(t) - p_1 E(t) = 0, \tag{130.9}$$

$$p_1 E(t) - kp_2 I(t)(1 - S(t) - E(t)) - \alpha I(t) = 0. \tag{130.10}$$

The feasible region for the equations is R^3, and so we study the equations in a closed set $A = \{(S, E, I) \in R^3 \mid S + E + I \leq 1, S, E, I \geq 0\}$.

From Eqs. (130.8) and (130.9), we can get $(\alpha p(t)I(t) + p_1 E(t) = 0$, and substituting it into Eq. (130.10), we have $\alpha p(t)I(t) - kp_2 I(t)(1 - S(t) - E(t)) - \alpha I(t) = 0$, we can get $I(t) = 0$. Substituting $I(t) = 0$ to Eq. (130.10), so $E(t) = 0$. Therefore, the system has the equilibrium $P^* = (S, E, I) = (S^*, 0, 0)(0 \leq S^* < 1)$.

Therefore, we can obtain the equilibrium for the system (130.5), $Q^* = (S^*, 0, 0, R^*)$, where $S^* + R^* = 1$. Next, we look at the stability of the equilibrium $P^* = (S^*, 0, 0)$.

Proof Let the Liapunov function be $V(S, E, I) = F(S) + G(E) + H(I)$, and taking the derivative of V versus t along the solution for the equations, we have

$$\begin{aligned} V'(S, E, I) = &- F'(S)kS(t)I(t) + G'(E)[kS(t)I(t) - \alpha p(t)I(t) - p_1 E(t)] \\ &+ H'(I)[p_1 E(t) - kp_2 I(t)(1 - S(t) - E(t)) - \alpha I(t)]. \end{aligned}$$

In order to ascertain $V(S, E, I)$ and $V'(S, E, I)$, and taking the value $F'(S) = 1$, $G'(E) = 1$, $H'(I) = 1$, we get $V(S, E, I) = S + E + I$, and

$$\begin{aligned} V'(S, E, I) = &- kS(t)I(t) + kS(t)I(t) - \alpha p(t)I(t) - p_1 E(t) \\ &+ p_1 E(t) - kp_2 I(t)(1 - S(t) - E(t)) - \alpha I(t), \\ = &\,\alpha[p(t) - 1]I(t) - kp_2 I(t)(1 - S(t) - E(t)) \le 0. \end{aligned}$$

So we get $V(S, E, I)$, which is positive definite, $0 \le V(S, E, I) \le 1 + S$, that is, it has an infinitesimally small upper bound and an infinite lower bound, and $V'(S, E, I)$ is a negative semi-definite in the feasible region $A = \{(S, E, I) \in R^3 | S + E + I \le 1, S, E, I \ge 0\}$.

From Theorem 130.2, the equilibrium P^* is globally uniformly asymptotically stable.

130.4 Results and Analysis

The probability that an unaware becomes a spreader or stifler is given a constant over the whole spreading process in traditional rumor propagation models, but in our model the probability is a variable which changes over time as can be seen in the above analysis. Event ambiguity also needs to be considered in the model, as it plays an important role in the rumor spreading process. In the following sections, we examine the results with a different values for parameter c to demonstrate how the clarity of the event affects rumor propagation. Simulations were carried out using MATLAB.

In this section, we carry out simulations to investigate the dynamics of SEIR model on two artificial networks. The artificial networks include ER random network and BA network. ER random networks with the same network size at $N = 10000$ and the same average degree $< k >= 16$ were chosen.

Firstly, comparing the results that the proposed model with same parameters was tested on this two artificial networks. Figure 130.3 corresponds to a case where $p1 = 0.5$, $p2 = 0.1$, $a = 0.1$, $c = 0.005$. It shows the general trends for the four kinds of agents in our rumor spreading model in random network and BA network. We can see that the density of $E(t)$ grows up, reaches a peak value, and then decreases. The density of $I(t)$ has the same trend line of change with the density of $E(t)$. Finally, the number of spreaders is zero and the spreading of the rumor terminates. When the system reaches a steady state, there are $S(t)$ and $R(t)$ nodes remain in the network.

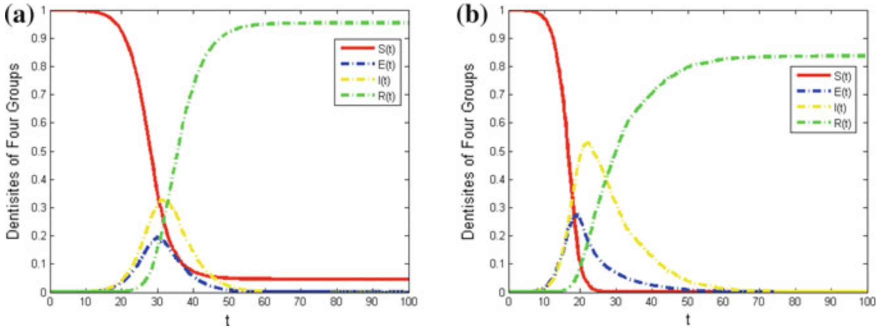


Fig. 130.3 **a** The model in WS network, **b** the model in BA network

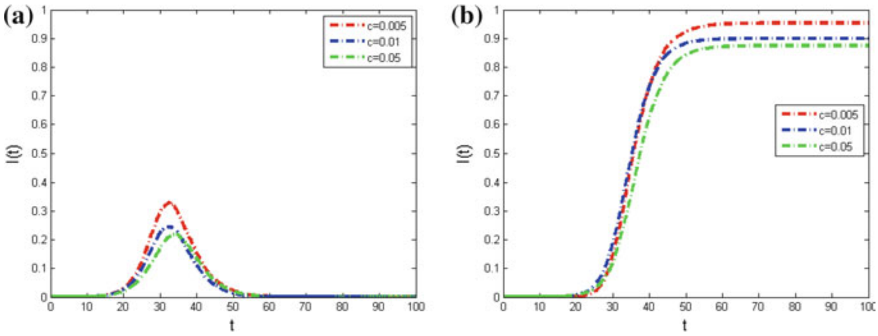


Fig. 130.4 Density of spreaders and stiflers on random networks with different c

These results are in accord with the analysis of dynamic equations. From this figure, it can be seen that the final rumor size $R(t)$ in random network is larger than the one in BA network. However, the time required for the rumor to reach the steady state on random network is later than the corresponding time on BA network. And the peak values of $I(t)$ on random network is lower than that on BA network. Thus, we conclude that the spreading scale on random network is bigger than that on BA network, while the spreading speed of rumor on BA network is much faster than that on random network. These results are consistent with the results in Refs [8].

Figures 130.4 and 130.5 comparing the results that the proposed model with different value for c was tested on this two artificial networks. Figure 130.4 illustrates how the density of spreaders and stiflers changes over time with different value for c in random networks. Given that the other parameters are fixed, we compared the rumor spreading processes on the two networks when $c = 0.005, c = 0.01, c = 0.05$ respectively. From a macroscopic perspective, we found that as parameter c decreased, the number of spreaders peaked and toward the end the size of stiflers increased, because a smaller c indicates a slower clear speed of event triggering rumors. Figure 130.4a describes how the density of spreaders changes with changes in the parameter c. It can be seen that the higher parameter c is, the smaller the spreader peak value.

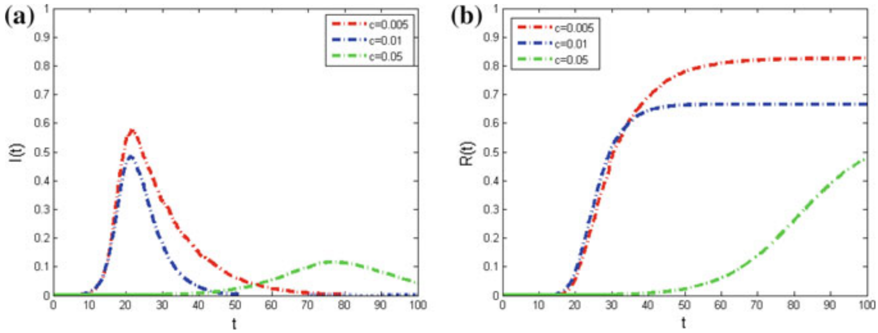


Fig. 130.5 Density of spreaders and stiflers on BA networks with different c

Therefore, the event ambiguity can be said to significantly affect the rumor spreading process. Figure 130.4b describes how the density of stiflers changes with c over time. The final value for the stifler density $R(t)$ is greater, which indicates the number of people affected by a rumor when c is smaller. Clearly, the smaller the value of c when other parameters are fixed, the broader the rumor's influence. A smaller c indicates that if events become clear more slowly, less spreaders change into stiflers, and therefore the influence of the rumor increases.

Figure 130.5 illustrates how the density of spreaders and stiflers changes over time with different value for c in BA networks. Similar to the random network, it can be seen that rumors spread more broadly and last longer when c is smaller. However, there is a more significant impact from ambiguity on rumor spreading in random networks. Figure 130.5a illustrates how the spreader density changes as parameter c changes. In the same situation, if the vague information lasts only a relatively short time, the rumors spread more quickly in BA networks than in random networks. That is to say, rumor spreading is sensitive to the ambiguity of events, which is related to the topology of random networks. Figure 130.5b describes how the density of stiflers changes as c changes over time.when parameter c is fixed, we can see that the rumor spreads faster and the final size of the stiflers $R(t)$ is smaller in random networks. In other words, rumors spread more broadly on random networks than on BA networks.

Because BA networks are closer to real social networks, we analyze the effect of the parameters p_1 and α. on BA networks respectively. Figure 130.6 illustrates how the spreader density changes as parameter p_1 changes in BA networks. Given that other parameters are fixed, the bigger the value of p_1, the bigger the rumors influence. Because p_1 is the transformation probability that lurkers become spreaders; in reality, along with the increase of p_1, there are more lurkers becoming spreaders. As a result, the number of spreaders increases, which increases the influence of the rumor. Figure 130.6b describes how the density of stifler changes as p_1. changes over time. It is easy to see the number of stifler is almost same when the spreading process terminate. The reason is that $E(t)$ is intermediate state of $I(t)$, all of $E(t)$ will become $I(t)$ as time goes by, transformation probability of $E(t)$ has no effect on the breadth of spreading.

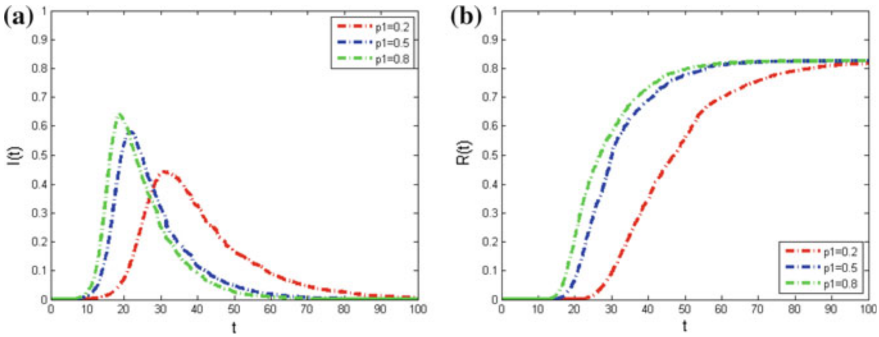


Fig. 130.6 Density of spreaders and stiflers on BA networks with different p_1

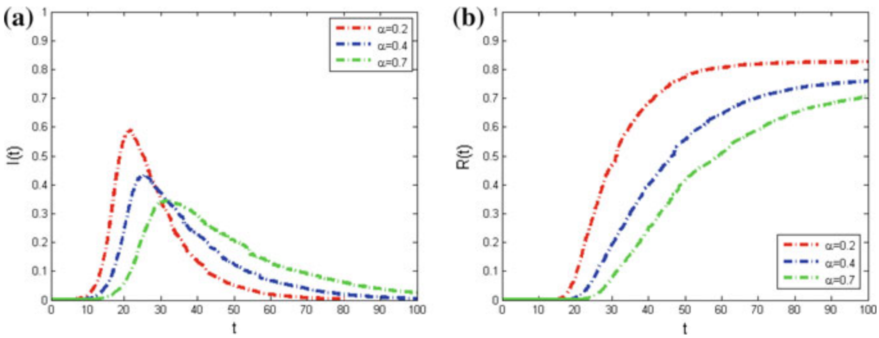


Fig. 130.7 Density of spreaders and stiflers on random networks with different c

Figure 130.7 shows how the density of spreader changes as α changes over time. Also, we can see in Fig. 130.7a that the bigger the value of α, when other parameters are fixed, the smaller the peak value of $S(t)$ and the final size of the stiflers $R(t)$. The rumor spreads faster and boarder when α is smaller. α is a forgetting probability, so a large α means that the individual that have great rate to forgot rumors in the spreading process, which can make more spreaders change into lurkers or stiflers and, therefore, decrease the influence of the rumor.

130.5 Conclusion

In this paper, we proposed a variant of the SEIR rumor spreading model by considering hesitating mechanism and the event ambiguity triggering rumors. In our opinion, people tend to judge the correction of the information when they heard a information, so the exposed state should be considered in rumor spreading model. And the ambiguous extent of an event plays an important role in the rumor spreading process. Although many researchers have proposed rumor spreading models, there are almost no models which consider the ambiguity of event. We considered the extend of ambiguity of event changing in time. Therefore, we brought a function $p(t)$ to describe the extent of ambiguity and the clear speed of an event in our model. This function as a parameter was added to dynamic differential equations, and a variant of the SEIR model was built. It reveals that considering dynamical behavior of rumor propagation is related to the fuzziness of event itself. We then compared the simulation results from our rumor spreading model using a different values for c in ER random networks and BA networks. A smaller c represents a slower clear speed, that is to say, the event is ambiguous for a longer time. The simulation results showed that a smaller c induces a broader and faster rumor spreading process. That is, the clear speed affects the rumor spread, and a smaller c enhances the spread. In reality, lack of clear information makes the public anxious to know the facts of the event, so rumors start which seek to explain the event and relieve their anxiety, so it is more likely they continue to believe and continue to spread the rumors. In addition, we find that although spreading scale on random network is bigger than that on BA network, the spreading speed of rumor on BA network is much faster than that on random network.

Acknowledgments This research was supported by project of Education Department in Sichan province (Grant No. 15ZB0295). We appreciated all support in finance and in spirit.

References

1. Allport GW, Postman L (1946) An analysis of rumor. Public Opin Q 10(4):501–517
2. Anthony S (1973) Anxiety and rumor. J Soc Psychol 89(1):91–98
3. Daley DJ, Kendall DG (1964) Epidemics and rumors. Nature 204(17):225–228
4. Han S, Zhuang F et al (2014) Energy model for rumor propagation on social networks. Phys A: Stat Mech Appl 394:99–109
5. Liu C, Zhang ZK (2014) Information spreading on dynamic social networks. Commun Nonlinear Sci Numeri Simul 19(4):896–904
6. Ma ZE, Zhou YC (2001) The qualitative and stability theory of ordinary differential equations (in Chinese)
7. Moreno Y, Nekovee M, Pacheco AF (2004) Dynamics of rumor spreading in complex networks. Phys Rev E 69(6):066,130
8. Nekovee M, Moreno Y et al (2007) Theory of rumour spreading in complex social networks. Phys A: Stat Mech Appl 374(1):457–470
9. Pendleton SC (1998) Rumor research revisited and expanded. Lang Commun 18(1):69–86
10. Peterson WA, Gist NP (1951) Rumor and public opinion. Am J Sociol 57(2):159–167
11. Strogatz SH (2001) Exploring complex networks. Nature 410(6825):268–276
12. Sudbury A (1985) The proportion of the population never hearing a rumour. J Appl Probab 22:443–446
13. Tang S, Jaho E et al (2011) Modeling gossip-based content dissemination and search in distributed networking. Comput Commun 34(6):765–779
14. Vannucchi FS, Prado CP (2009) Sznajd model and proportional elections: the role of the topology of the network. Int J Mod Phys C 20(06):979–990
15. Wang J, Zhao L, Huang R (2014) Siraru rumor spreading model in complex networks. Phys A: Stat Mecha Appl 398:43–55
16. Xia LL, Jiang GP et al (2015) Rumor spreading model considering hesitating mechanism in complex social networks. Phys A: Stat Mech Appl 437:295–303

17. Zanette DH (2002) Dynamics of rumor propagation on small-world networks. Phys Rev E 65(4):041,908
18. Zhao L, Qiu X et al (2013) Rumor spreading model considering forgetting and remembering mechanisms in inhomogeneous networks. Phys A: Stat Mech Appl 392(4):987–994

Chapter 131
The Study on the Credit Risk Assessment of Borrower in P2P Network of China

Dan Jiang and Xiaoqin Li

Abstract On account of the rapid development of modern network technology, more and more online financial services come to being. Take P2P network as an example. Now, such financial services model in our country is taking great risk. This is mainly a study on credit risk. Based on BP neural network, P2P network platform credit risk evaluation model were built to train and simulate. The results show that the final data generated by these models are of practical value. It is capable of using P2P network platform on personal credit risk evaluation scientifically. At the end of the article, some valuable suggestions are put forward in regard to P2P network loan personal credit risk evaluation system.

Keywords P2P network · BP neural network · Credit Risk

131.1 Introduction

P2P network, by means of network, is a new lending mode essentially and it is an innovation in terms of the traditional way of private lending terms. Compared with the past lending mode, this online financial service contains much more merits with low financing requirement; easy operation and low risk. The borrowers can raise money in a relatively short period of time, while the loaner can lend the money to more than one borrower to have the risk decentralized at the most extent. With the development of Internet technology, P2P microfinance has gradually evolved into P2P network. P2P network platform has extremely attracted people's eyes. Since 2005, a well-known P2P network platform in Britain, named Zopa.com, after four years of reform and progress, has constantly expanded their business scope. And its market has spread to Spain, Japan and other regions. In 2014, the sums of loan project involved about 270 million pounds. Although this kind of network financial

D. Jiang (✉) · X. Li
Chongqing Technology and Business School, Chongqing 600000,
People's Republic of China
e-mail: 719221214@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_131

service in our country develops relatively late, affected by the rapid development of the social financial industry, it is in a quick speed now. In June 2007, the first P2P network platform established–ppdai.com, and since then become popular in our country. According to the data related P2P focus, by the end of April 2015, the network financial service platform of this kind is about 1819. Its rapid development has received more and more attention from borrowers. According to a report in the home of net,the lending in the first half of this year, lending projects involved in the transaction reached 300.619 billion yuan.

P2P network platform is developing so quickly because of its incomparable advantages that traditional finance cannot be compared with it. P2P network not only speeds up the disintermediation but improves the utilization of idle funds [8]. Compared with the traditional bank loans, P2P network can reduce the financing costs [1] and bring convenience to personal finance, which makes the banking system come true [5]. Under such social background that most small scale enterprises usually have financing difficulties, this kind of Internet banking services can cut the financial charges of these enterprises, so that micro and small business can get rid of their trouble and get better development [3].

However, investors will still face higher credit risk in such network financial service. Firstly, most parts of Internet lending have not required borrowers to use pledge, so if the borrowers break their promise, the investors can hardly redeem most of their loss; Secondly, the investors can only make investment decision according to the borrowers' information from P2P network platform, which exists a phenomenon of converse choice; Thirdly, without the professional knowledge of diversified investment, it is difficult for individual investors to make optimal investment decision in practice. Thus, after exploration and analysis, the borrowers' credit risk are of great value significance in this kind of network financial service.

131.2 Literature Review

Zhu and Lei [12] argued that such a network of financial services companies tend to focus on controlling the internal risk, and exploring a lot in the credit risk prevention mechanism of exploration. However, many problems still exist in the actual development process. To further standardize the P2P network platform development, they put forward ideas to reform from the policy environment, regulation and the platform level aspects and continuously improve self perfection.

Wu and Cao [9] proposed to divide the network financial service into the scope of regulation, and then to design the regulation principle, content and so on, in order to the guarantee the development of stable for a long time.

Miao [4] pointed out that "peer-to-peer lender" continuous innovation aims to face the risk of gradually highlighted, the risk of industry development formed the negative effect is very outstanding.To some extent, it also formed certain threat to the country's financial security. If you want to completely solve the problem of peer-to-peer lender,the country and the regulatory net lending industry must form as a whole and make it develop healthily.

These studies have emphasized the risk which was caused by the P2P network platform must introduce the corresponding laws and regulations. But these studies neglected the P2P network itself lacks the borrowers credit risk evaluation model. Of course, except this perspective analysis, there are many scholars thinking that net credit operation mode for P2P network platform are equally important. Greiner and Wang' [2] research shows that Prosper are relatively perfect credit system. In Prosper platform, the borrower should not only provide your basic information (such as marital status, income level, the condition of basic assets, etc.), but also submit the social security number, driving license number and other information effectively.

Wang, Yuan and Zhong [7] summed up that the operation mode has two characteristics: the first is, based on the reference of risk prevention system of Zopa, to require loaners who raise funds on network platform to repay the debt in a specific time; Followed by using audit credit way, specifically is residence booklet of loans through the network platform to raise funds and other relevant certificates, etc. should be included in credit audit system.

Credit Ease, the mainstream P2P network platform in China, provides customers with unsecured and unsecured small loans. Its main customer base is the workers, college students, the private owners and farmers. Zhang [10] argued that Credit Ease reflected a distinct feature of running patterns is to design a new "P2P credit to help farmers platform" to increase farmers' income, and farmers' interest and management fee charges is less. In this way it unites the commonweal and commercial integration, and lays a more solid foundation the company's business expansion. Of course, to some extent, these studies still play a role in evaluating P2P network borrowers' credit risk in our country. But these studies are insufficient. Few scholars make further researches to P2P network from the aspect of the evaluation metrics of Internet finance credit and in combination with online behavior and the evaluation metrics of P2P network credit. Compared with some small and micro-sized enterprises and common personal clients, banks are more willing to provide loans for state-owned enterprises or government-financed platforms. Even though they agree to provide loans for these groups, collateral are required. With the great impact that Internet finance have caused to the financing activities of traditional financial institutions, traditional financial institutions have started to expand a new financing method, i.e. unsecured loans. However, Beibu Gulf Bank in Guangxi has released a new financial product to individual businesses and small-sized enterprises. The requirements are low that any Chinese legal citizens who have lived in Nanning for some time can make applications to it. This makes it more convenient for them to make a loan. Obviously, it is of significance to put forward the model of evaluating personal credit risk. When the evaluation of one's credit is good, not only the impossibility of the cash withdrawing because of the excessive frequency of transactions can be avoided, but also P2Pnetworkcan encourage traditional financial industry to seek innovations. Thus, domestic bond market yields are rising and funds are circulating all around. And domestic demand and consumption are expanded [6]. As a result, from the angle of the evaluation metrics of cyber behavior, BP neural network is introduced in this article to specifically study the evaluation of P2P network borrowers' credit.

131.3 Simulation of BP Neural Network Model

131.3.1 Index Selection

Personal information required by P2P network is easy. It generally includes his identification, basic property status, age, educational background and so on. After this, the information about someone who would like to raise funds by P2P network platform will be investigated. Providing the borrower's information, the borrower will be evaluated systematically in the level of credit rating. The results will then be published to the Internet. So, according to the index selection principle, there are six levels about the information of the borrowers on P2P network platform. The specific details are listed in the tables (Table 131.1):

Table 131.1 P2P individual credit risk evaluation index system neutral

Age	18 to 25 Years old	25 to 30 Years old	30 to 35 Years old	35 to 40 Years old	40 to 45 Years old	45 to 50 Years old	50 to 55 Years old	55 to 60 Years old
Value	0.7	0.8	0.9	1	0.9	0.8	0.7	0.6
Literacy	Primary school	Junior school	high	High school	Junior college	College	Master	
Value	0	0.1		0.3	0.5	0.7	1	
Marital status	Unmarried	Married	Divorce					
Value	0.5	1	0					
Income level	Within 5000 yuan	5000 to 10000 yuan	Over 10000 yuan					
Value	0.5	0.7	1					
Housing situation	Renting	Within 50 m^2	50 to 100m^2	100 to 150 m^2	Over 150 m^2			
Value	0.2	0.4	0.6	0.8	1			
Default number	Over 20	10 to 20	5 to 10	Within 5	0			
Value	0	0.2	0.4	0.6	1			

131.3.2 Data Acquisition

From P2P network platform transactions of PPDAI, peer-to-peer lender, CreditEase, LUFAX, the paper selected 70 borrowers' information record without default and 30 borrowers' information record with default, with a total of 100 P2P group information, as the samples of this P2P credit risk evaluation. According to the result of the borrower's information value and the result given by P2Pplatform, the credit risk rating is divided into 5 levels, specific sample data in the Tables 131.2 and 131.3:

131.3.3 Normalization Processing

The seven variables and one output variable values were showed in this paper. Ready input neural network model, the samples of neural network input values are generally needed to have normalized processing; the input amount of normalized to [0, 1]. This method of normalization which is used in the article is maximum minimum value method; its function is as follows:

$$f(u) = \begin{cases} 1 & u \leq a, \\ \dfrac{u-a}{b-a} & a < u < b, \\ 0 & u \geq b. \end{cases} \tag{131.1}$$

Then through maximum minimum value method–normalized function and data collection, and use the following formula to normalize:

$$u_i^* = \frac{u - \min(u)}{\max(u) - \min(u)}. \tag{131.2}$$

Because maximum minimum value method for data normalization processing is a kind of linear transformation, it can better retain its original meaning without the loss of too much information.

131.3.4 The Construction of the Model

This paper uses the three layers of neural network to simulate P2P network borrower credit risk evaluation process, the input layer node number is 6, such as age, literacy, marital status, income level, housing situation, the frequency of default. The actual amount of hidden layer nodes is 10, the corresponding output node for a total

Table 131.2 P2P individual credit risk evaluation index value (1)

Order number	Age	Literacy	Marital status	Income level	Housing situation	Default number	Credit risk rank
1	0.8	0.3	1	0.5	0.8	0.6	0.6
2	0.9	0.3	1	0.5	0.2	0.6	0.4
3	1	0.1	1	0.5	0.2	0.2	0.2
4	0.9	1	1	1	0.6	0	0.4
5	1	0.5	1	1	0.6	0.2	0.6
6	0.8	0.7	0	0.1	0.6	1	0.8
7	0.9	0.3	0.5	0.5	0.8	1	0.8
8	0.8	0.7	1	0.5	0.2	1	0.8
9	1	0	1	0.5	0.2	1	0.6
10	0.8	0.5	1	1	0.6	1	1
11	0.9	0	1	0.7	1	1	0.8
12	1	0.3	1	0.5	0.4	1	0.8
13	0.9	0.5	1	1	0.6	1	1
14	0.8	0.5	0.5	0.7	0.2	1	0.8
15	0.8	0.3	1	0.5	0.6	1	0.8
16	1	1	0.7	1	0.2	0.2	0.4
17	0.9	0.3	0	0.5	0.2	0.4	0.2
18	0.9	1	1	0.5	0.6	1	0.8
19	0.8	0.3	1	0.7	1	0.6	0.8
20	0.9	0.7	1	0.7	0.2	0.2	0.4
21	1	0.3	1	0.5	0.2	0.2	0.4
22	0.9	0.7	0	0.7	0.8	0.4	0.4
23	1	1	0	1	0.8	0.4	0.4
24	0.9	0.5	0	0.5	0.4	0.4	0.4
25	1	0.5	0.5	0.7	0.2	1	0.8
26	0.9	1	0.5	0.7	0.2	0.6	0.6
27	0.9	0.5	0.5	1	0.2	0.4	0.4
28	0.8	0.5	1	0.5	0.8	0	0.4
29	0.9	0.3	1	0.7	0.2	0.2	0.4
30	0.9	1	1	0.5	0.6	0.6	0.6
31	0.8	0.5	1	0.5	0.4	0.6	0.6
32	1	0.5	1	1	0.6	0.2	0.6
33	0.9	0.7	1	1	0.4	0.6	0.8
34	0.7	0.7	1	1	1	0.6	0.8
35	0.8	0.3	1	0.5	0.8	0	0.4
36	0.8	0.3	0	0.7	1	0.6	0.6
37	0.9	0.3	0.5	0.5	0.2	0	0.2
38	0.9	1	1	0.7	1	1	1
39	0.9	0.7	0.5	0.7	0.2	1	0.8

(continued)

Table 131.2 (continued)

Order number	Age	Literacy	Marital status	Income level	Housing situation	Default number	Credit risk rank
40	0.8	0.3	1	1	0.4	1	0.8
41	1	0.7	1	0.7	0.8	1	1
42	1	1	1	0.5	0.6	1	0.8
43	0.9	0.3	1	0.5	0.2	1	0.8
44	0.8	0.7	0.5	1	0.4	1	0.8
45	0.6	0.3	1	1	0.8	1	1
46	0.6	1	1	0.5	0.8	0.2	0.4

Table 131.3 P2P individual credit risk evaluation index value (2)

Order number	Age	Literacy	Marital status	Income level	Housing situation	Default number	Credit risk rank
47	0.9	0.5	1	1	0.4	0.2	0.4
48	0.8	0.7	1	1	0.6	1	1
49	0.7	0.3	0	0.5	0.8	1	0.8
50	0.9	0.3	1	0.5	0.2	1	0.8
51	1	1	1	0.5	0.6	1	0.8
52	1	0.7	1	0.5	0.6	1	0.8
53	0.8	0.3	1	1	0.6	1	1
54	0.9	0.7	1	0.7	0.4	1	0.8
55	1	0.3	1	0.5	0.6	1	0.8
56	0.9	0.3	0	0.5	0.6	1	0.8
57	0.9	1	1	0.5	0.6	1	0.8
58	1	0.5	0.5	0.5	0.4	1	0.8
59	1	0.7	1	1	0.6	1	1
60	0.9	1	0.5	1	0.6	1	1
61	0.9	0.5	1	0.5	0.2	1	0.8
62	0.8	0.5	1	1	0.8	1	1
63	0.9	0.7	0.5	0.7	0.2	1	0.8
64	0.9	1	1	0.5	0.4	1	0.8
65	0.9	0.5	0.5	1	0.8	1	1
66	1	1	1	1	0.6	1	1
67	0.9	0.7	1	1	0.8	1	1
68	0.7	0.3	1	1	1	1	1
69	0.8	0.3	1	1	0.8	1	1
70	0.9	1	1	1	0.6	1	1
71	1	1	1	1	0.6	1	0.8

(continued)

Table 131.3 (continued)

Order number	Age	Literacy	Marital status	Income level	Housing situation	Default number	Credit risk rank
72	1	0.3	1	0.5	0.4	1	0.8
73	0.8	0.3	1	0.5	0.8	1	0.8
74	0.9	0.7	1	1	0.8	1	1
75	1	0.3	1	0.5	0.4	1	0.8
76	1	0.1	0	0.5	0.2	0.4	0.2
77	1	0.7	1	1	0.4	0.6	0.8
78	0.7	0.3	1	0.5	1	1	0.8
79	0.6	0.7	1	1	0.6	1	1
80	0.8	0.5	0.5	0.5	0.2	1	0.6
81	0.9	1	0	1	0.6	1	0.8
82	0.9	0.1	0	0.5	0.6	1	0.6
83	1	0.5	0	0.5	0.6	1	0.8
84	1	0.7	1	1	1	1	1
85	0.9	1	0.5	1	0.8	1	1
86	0.9	0.5	1	0.5	0.6	1	0.8
87	0.8	0.5	1	0.7	1	1	1
88	0.9	0.3	1	0.7	0.6	1	0.8
89	0.9	0.1	0	0.5	0.4	1	0.6
90	1	0.5	0	0.7	0.2	1	0.6
91	0.9	0.7	1	0.7	1	1	1
92	0.9	1	1	1	0.6	1	1
93	0.9	1	1	1	0.6	1	1
94	0.8	0.7	1	1	0.6	1	1
95	1	0.5	0	0.7	0.4	1	0.8
96	1	0.7	1	1	0.6	1	1
97	0.9	0.1	1	0.7	0.6	1	1
98	0.7	0.5	1	0.5	0.2	1	0.8
99	0.8	0.7	1	0.5	0.6	0.2	0.4
100	0.9	0.3	0	0.7	0.4	1	0.8

amount is 1. Because both the input vector and output vector is not in conformity with the linear relationship, single polarity Sigmoid is used as transfer function; the corresponding mathematical type as follows:

$$f(u) = \frac{1}{1 + e^{-u}}.$$

131.4 Model Simulations

The author has made corresponding training and simulation operations by Mat lab in this article. After repeated experiments, to extract the ideal level training error, he started to train the neural network and thus obtained the specific weights and thresholds, and then established the corresponding evaluation model. The mode was set up and then analyzed carefully and forecasted data validation at last. The credit risk evaluation of the accuracy was predicted at the time of lacking such financial services network information.

131.4.1 Training Process and Results

In the process of simulation, the former 95 data among the 100 data as training data, and fitting, contains 29 borrowers who have default record and 66 borrowers who have no default record. The total amount of the borrowers who have default record is one and the borrowers who have no default record are 4 in the first 96–100 of information extraction, Using "train" function to train the BP neural network,

$$\begin{aligned}
&\text{net} = \text{newff(pn_train,tn_train,10)}\\
&\text{Net.trainParam.epcohs} = 1000\\
&\text{Net.trainParam.goal} = le - 3\\
&\text{Net.trainParam.show} = 10\\
&\text{Net.trainParam.lr} = 0.1.
\end{aligned}$$

The "p" is the input matrix after pretreatment, "t" is the output results. When the network step length is 1000, the expected targets error is 0.001, 10 cycles show a convergence curve changes, learning step length is 0.1.

As shown in Fig. 131.1, BP neural network model can meet the target requirements of precision after four iterations. As a result, the model is practical and accurate. As shown in Fig. 131.2, network output risk is similar to actual assessment level, being in a good condition.

131.4.2 Simulation Process and Results

After the training and fitting, the corresponding predictions unfold careful verification.

$$t\_\text{final} = \text{sim(net, } p\text{\_test)}.$$

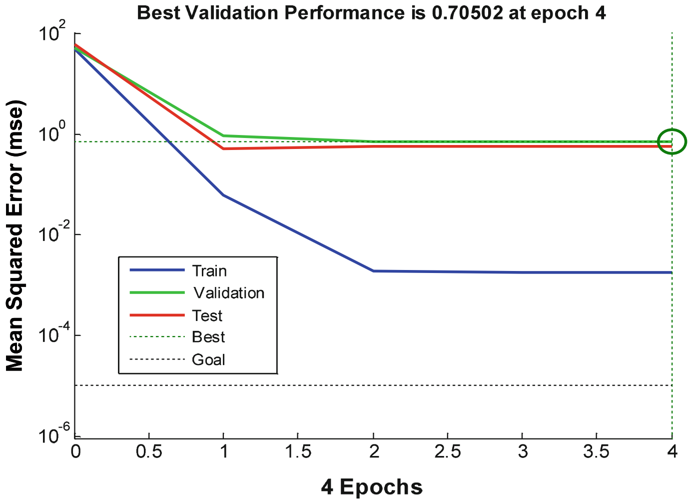


Fig. 131.1 Training Results

Fig. 131.2 Comparison diagram

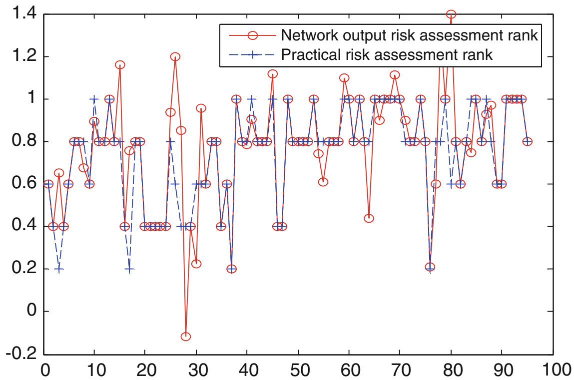


Table 131.4 The target output compared with model output

	Borrower 96	Borrower 97	Borrower 98	Borrower 99	Borrower 100
Target output	1	1	0.8	0.4	0.8
Model output	0.987213	0.998456	0.809303	0.409453	0.759145

Among them, the function Simis a simulation function, and P_test is a data which needs forecast after pretreatment. After the validation data input from 95 to 100 results, the target output compared with model output are as follows: As shown in Table 131.4, according to the 95 data of borrowers for training and simulation, model output and target output are basically identical. It is obvious that such evaluation model accuracy is very good.

Table 131.5 Three types of output

	Borrower 96	Borrower 97	Borrower 98	Borrower 99	Borrower 100
Target output	1	1	0.8	0.4	0.8
Model output	0.987213	0.998456	0.809003	0.409454	0.759145
Model output of lack of education level	0.968452	0.957345	0.744924	0.388231	0.721295

131.4.3 Simulation Results of Lack of Data Validationc

Because the network financial service data is collected by the entry of the borrowers, there will be a shortage of information, resulting in the financial services platform to validate personal information, there is a certain number of invalid information. And on the premise of insufficient information, the new evaluation system can still be with the help of the training effect, obtain accurate results. In this paper, eliminating cultural degree index from 96 to 100 data, and verify the prediction results of model. In the lack of information about cultural degree, the target outputs compared with the model output are as follows: As shown in Table 131.5, under lack of information of education level, compared with complete information model output, there are some differences, but the overall model output and target output basically remains the same Thus, it can be seen that in the case of lack of information of education level, the BP neural network model can forecast credit evaluation of the borrower in P2P network, and it is in a higher accuracy of thee valuation.

131.5 Conclusions

The risk assessment model discussed in this article, through the training of the borrower credit information, rectify and reform all the neural unit specific connection weights in the corrective model, clear input and output of actual connection and obtain accurate measurement results. But defects still exit in the process of evaluation, for example, training can't leave plenty of data; the network structure has certain difficulty in construction. However, in view of these shortcomings, the partial derivative of error functions can strengthen the explanatory ability of the neural network method by introducing fuzzy logic. Using the model analyzes the individual credit situation, Ali small loans has done better in this respect. In Berger and Udell model analysis framework, Ali small loans use Ali cloud, Alipay and Taobao and Alibaba website that wrap the huge amounts of data. Using huge customer resources, trading and credit data, and the analysis of the data mining for customer credit rating, finally, get the conclusion of "small amount, short time limit and increases with the increasing borrow also" of unsecured small loans and mortgages [11].

For the research results above all and the requirements of objective environment for credit risk assessment, the following views are put forward: first of all, the relevant legal system about this kind of lending model must be improved. P2P network in our country is lack of legislation and regulation. In order to better standardize legal financing and personal loan, CBRC should enact the law about P2P network as soon as possible; next, strengthening personal moral cultivation. Personal credit is closely linked with moral cultivation. The promotion of moral cultivation can also make personal credit improve. Individuals can learn excellent traditional culture or follow the example of moral model to strengthen the personal moral accomplishment and enhance personal credit. Besides these, the government should increase the popularize strength of moral cultivation. At last, make the best of executive's coordination and optimize level of management. The management methods for credit industry in our country's industry and trade ministry are closely related to reformation and progress of this profession. Accordingly, China's industry and trade ministry should give due attention to the development of P2P network platform and take reasonable measures to scientifically manage it.

References

1. Freedman S, Jin G (2008) Dynamic learning and selection: the early years of prosper. com. Working paper, University of Maryland
2. Greiner ME, Wang H (2009) The role of social capital in people-to-people lending marketplaces. In: Proceedings of the ICIS, p 29
3. Lu X, Wang L, Xi Y (2011) Research on the financing cost of internet banking and small and micro enterprises. Manage Modern 5:7–9 (in Chinese)
4. Miao X (2012) P2P network credit risk and prevention. Gansu Province Financial pp 20–23 (in Chinese)
5. Qian J, Ye Y (2012) The development and prospect of network lending of China. In: Financial forum, pp 46–51 (in Chinese)
6. Qu Q, Chen L, Yu W (2013) Analysis on the influence of internet financial development on financial market and bond market. Bond 10:29–35 (in Chinese)
7. Wang Z, Yuan Z, Zhong X (2012) Research on the operation mode of micro credit in P2P network of China case analysis based on ppdai and yinongdai. New Financ 2:72–73 (in Chinese)
8. Wen X, Wu X (2014) P2P analysis of influential factors on the success rate of network–take ppdai as an example. In: Financial forum, pp 3–8 (in Chinese)
9. Wu X, Cao Y (2011) The discussion of strengthening the supervision of P2P network platform. South Financ 4:52–59 (in Chinese)
10. Zhang (2012) P2p business model and legal analysis of loan service platform–take Yi Xin corp. as an example. PhD thesis, Beijing university, Beijing (in Chinese)
11. Zhao H, Chen (2015) Internet technology, internet banking and small and medium sized enterprise loan technology innovation-take Ali small loans as an example. J Univ Electron Sci Technol 17:2–5 (in Chinese)
12. Zhu B, Lei W (2012) P2p the new development of the private lending platform and the analysis of its supervision and guidance. Rural Financ China 19:53–54 (in Chinese)

Chapter 132
Research on Financing Risks of Green Residential Buildings: A Case Study of the Chengdu Langshi Green Blocks

Liang Liu

Abstract Financing risks evaluation of green residential buildings is conducted in this paper, based on fuzzy comprehensive evaluation method. The Chengdu Langshi green blocks project is used as a case-study for evaluating financing risks. The results show that real estate development enterprises of Sichuan province are of greater financing risks. The most influential risk factors are laws and policies, enterprise financial position, corporate reputation, enterprise management, macroeconomics, and industry competition, in that order. The results demonstrate measurement of financing risks using a case study, which is useful for the financing risk management of green residential buildings.

Keywords Green residential building · AHP · Fuzzy comprehensive evaluation · Financing risk

132.1 Introduction

In recent years, with the continuous increase in the smoggy days, environmental protection and green economy are increasingly becoming the focus of public attention. Chasing after a healthier lifestyle, more and more property buyers are starting to show interest in green residential products, in pursuit of high-quality living experience. In order to promote a robust growth in green buildings with the reduction in building energy consumption, construction waste and air pollutants, the government has introduced policies geared towards advancing the "green transformation" of the construction industry. By the end of 2015, China will have completed one billion square meters of new green building construction, with over 50 % of the new residential projects achieving green standards. In 2014, the Sichuan Province Department of Housing and Urban-Rural Development announced a set of local policies and

L. Liu (✉)
School of Construction and Management, Xihua University,
Chengdu 610039, People's Republic of China
e-mail: 25146406@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_132

procedures devised to promote the adoption of green building operations, by providing further incentives for the construction and development of green building at the provincial level.

Green building refers to the building practice of maximizing energy savings, enabling environmental protection and reducing pollution, while providing healthy, practical and efficient use of internal space; the natural harmony of the building is emphasized during its full life cycle. The core concept is to maximize the conservation of resources, protect the environment, take advantage of new technologies and materials with positive environmental impact, adopt green building construction practices that are energy efficient; all of these are in line with the sustainable green lifestyle and way of work [1].

Recent research on green buildings is mainly focused on the areas of technological innovation and application in energy conservation and environmental protection, evaluation of green buildings and their economy, their whole life cycle cost and incremental cost, as well as investment and financing modes. There is a lack of research on the financing risks of developing green buildings. Since the green residential concept is relatively new in China, with higher construction cost than the conventional housing projects, the project financing risk is one of the key issues in the development of green buildings. Therefore, the financing risk associated with green building projects is the primary focus of the present study. Drawing lessons from the domestic and foreign research in this area, this paper uses the AHP and fuzzy comprehensive evaluation method to construct a financing risk evaluation model of green buildings. The Langshi green project in Chengdu is then used as a practical application of the method for financing risk assessment of such projects. Since green housing represents a new direction of real estate development in China, the subject of this paper is of great significance as the assessment of main financing risk factors and their relative importance is critical in controlling and reducing the financing risks for the success of these development projects.

132.2 Construction of Fuzzy Comprehensive Evaluation Model Based on AHP

The fuzzy evaluation method of AHP is to construct analytic hierarchy structure and apply fuzzy mathematics for comparison and decision making. Based on the evaluation criteria as well as actual measurements, this method provides a comprehensive evaluation of things or systems after applying fuzzy transformation [3]. The steps of the method are as follows:

132.2.1 Construction of Analytic Hierarchy Structure

There are a wide variety of contributing factors regarding the financing risk of green buildings. In reference to Green Building Evaluation Standard (GB/T5 0378-2006), and drawing lessons from the various national green building projects in practice, the main risk of financing of green housing projects in Chengdu city of Sichuan province is analyzed based on survey data; the financing risk evaluation model is constructed as shown in Fig. 132.1. The first layer of the financing risk evaluation model is the financing risk, which is the target layer. Green housing projects in Chengdu primarily rely on debt financing, with equity financing being of relatively small proportion. Debt financing mainly consists of bank loans, bonds, private lending and advance sale/rent. Equity financing includes stock listings and asset restructuring. These six means of financing constitute the second layer of the model, i.e. the criterion layer. The third layer is the program layer that consists of the policy and legal factor, macroeconomics, industry competition, corporate reputation, enterprise financial situation, and management factor. These six types of financing risk factors are commonly associated with the six financing means.

$$D = \{D_1, D_2, \ldots, D_6\},$$

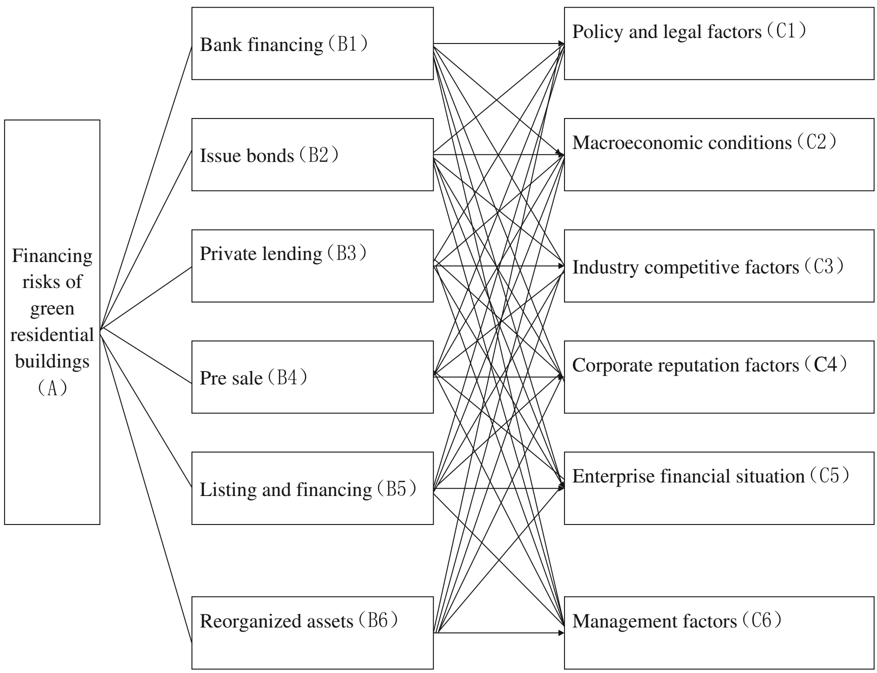


Fig. 132.1 Financing risk evaluation model

where D is a set of the risk factors affecting the financing of green residential building projects, in which the six main components are listed.

132.2.2 Calculation of the Weights of the Financing Risk Factors

$W = \{w_1, w_2, \ldots, w_6\}$, obtained from the judgment matrix based on the expert scoring structure. First calculate the nth root of Mi which is the product of the matrix elements for each row of the judgment matrix: $W_i' = \sqrt[n]{\prod_{j=1}^{n} B_{ij}}\ (i, j = 1, 2, 3 \ldots n)$.

This results in a vector $W = \left[W_1', W_2', W_3' \ldots W_n'\right]^T$; the normalization of this vector yields the risk factor weighting vector [2]. The weight calculation process is shown in Fig. 132.2.

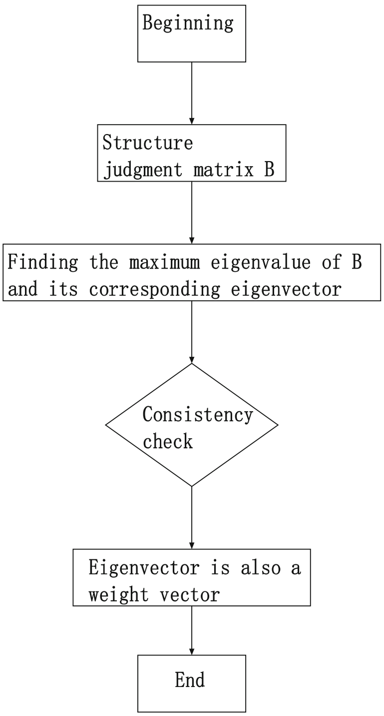


Fig. 132.2 Weight calculation degree diagram

132.2.3 Application of Fuzzy Statistical Method on the Financial Risk Factor Expert Scores

$$V = \{\text{Great risk, Significant risk, General risk, Less risk, Little risk}\} = \{1, 2, 3, 4, 5\}.$$

After the scoring, the normalized fuzzy evaluation matrix $R = \{R_1, R_2, \ldots, R_n\}$ is obtained where R_i is the fuzzy evaluation vector of the ith factor.

132.2.4 Fuzzy Comprehensive Evaluations

The establishment of the first level fuzzy comprehensive evaluation model:

Fuzzy evaluation of bank loan: $R_{B1} = W_{B1} \times I_{B1} = [a_1, a_2, a_3, a_4, a_5]$.

The fuzzy evaluations of other financing methods, including the bond issue, private lending, pre sale, listing and financing, and reorganized assets, are similarly established.

The establishment of the second level fuzzy comprehensive evaluation model: Based on the evaluation vectors of the first level fuzzy evaluation model such as R_{B1}, R_{B2}, R_{B3}, R_{B4}, R_{B5}, R_{B6}, the second level fuzzy evaluation matrix can be established as:

$$I = \begin{bmatrix} a_1 & a_2 & a_3 & a_4 & a_5 \\ b_1 & b_2 & b_3 & b_4 & b_5 \\ c_1 & c_2 & c_3 & c_4 & c_5 \\ d_1 & d_2 & d_3 & d_4 & d_5 \\ e_1 & e_2 & e_3 & e_4 & e_5 \\ f_1 & f_2 & f_3 & f_4 & f_5 \end{bmatrix},$$

$$R = W \times I = [q_1, q_2, q_3, q_4, q_5].$$

132.2.5 Evaluation of the Level of Financing Risk of the System

The weighted average is calculated as: $T = \frac{\sum_{i=1}^{5} v_i R_i}{\sum_{i=1}^{5} R_i}$.

The numerical value of T is between $1 \le T \le 5$. The evaluation results of T can be obtained from Table 132.1.

Table 132.1 Table of the corresponding relations between T and evaluation results

Evaluation results	Great risk	Significant risk	General risk	Less risk	Little risk
T	$T \prec 2.0$	$2.0 \leq T \prec 2.8$	$2.8 \leq T \prec 3.5$	$3.5 \leq T \prec 4.0$	$T \geq 4.0$

132.3 Engineering Case Analysis

132.3.1 Background of the Engineering Project

The Langshi green blocks in Chengdu is a high-tech residential development that combines comfort and low energy consumption. The project is located in Chengdu East Second Ring Road, opposite the Tower Hill park. It is the core residential sector within the government development planning of the 'east side center' and 'Chengdu village' area. The construction area of this project is 84385 square meters, covering an area of 21472 square metres, with a green rate of 30 %, a volume rate of 2.9, and North South facing. It is considered a highly desirable residential area in the main urban region. The Langshi green blocks use GSHP technology system, which can achieve indoor temperature control without additional air conditioning units and ease sudden temperature changes affecting those such as the newborns and pregnant women. Those with cardiovascular or respiratory diseases may also benefit. With the distinct local geographical and climatic environment, the Langshi green blocks project leverages the professional real estate development experience in green technology and aims to create a healthy, comfortable, people oriented and sustainable development with the attention to details. This development will be the first national green building three stars project in Chengdu.

132.3.2 Financing Risk Assessment

(1) Construction of Analytic Hierarchy Structure
Figure 132.1 is the financing risk evaluation model.

(2) Application of AHP Method to Determine the Weight of Evaluation Factors
Based on the expert scores, the various levels of the comparison judgment matrix are constructed.

The normalized weight of the second layer to the first layer:

$$W_B = (0.3822, 0.0435, 0.0832, 0.3034, 0.1637, 0.0240).$$

The weight of the third layer to the first layer:

$$W_c = (0.2990, 0.1055, 0.0631, 0.1435, 0.2590, 0.1299).$$

From the results, it can be concluded that the most influential financing risk factors of the Langshi green block project are policy and law, enterprise financial situation, corporate reputation factors, enterprise management factors, macroeconomic factors and industry competition factors, in that order.

(3) The Evaluation Set and the Single Factor Evaluation

The evaluation set:

$$
\begin{aligned}
V &= \{v_1, v_2, v_3, v_4, v_5\} \\
&= \{\text{Great risk, Significant risk, General risk, Less risk, Little risk}\} \\
&= \{1, 2, 3, 4, 5\}\,.
\end{aligned}
$$

The single factor evaluation is determined from five expert scores, evaluating the six types of influence factors on the bank loans. For the policy and legal factors, one of the experts judges that the risk is very large, three think it is of significant risk, one considers it is of general risk. The other risk factors are assessed in a similar manner. The evaluation results are shown in Table 132.2.

For the single factor evaluation of the bank loans (Table 132.3), the results are summarized in Table 132.4. The single factor evaluation matrix I_{B1} is obtained after normalization.

Table 132.2 Green building financing risk weight calculation

	Banking financing	Issue bonds	Private lending	Pre sale	Listing and financing	Reorganized assets	Weight
Banking financing	1	7	5	2	3	9	0.3822
Issue bonds	1/7	1	1/3	1/7	1/5	3	0.0435
Private lending	1/5	3	1	1/5	1/3	5	0.0832
Pre sale	1/2	7	5	1	3	9	0.3034
Listing and financing	1/3	5	3	1/3	1	7	0.1637
Reorganized assets	1/9	1/3	1/5	1/9	1/7	1	0.024

Table 132.3 Single factor expert evaluation results

Experts	$C1$	$C2$	$C3$	$C4$	$C5$	$C6$
A	1	3	5	3	2	4
B	2	4	5	3	3	4
C	2	4	5	3	2	4
D	2	4	5	4	2	5
E	3	3	4	3	3	4

Table 132.4 Single factor evaluation

Banking financing	Evaluation set				
	Great risk	Significant risk	General risk	Less risk	Little risk
$C1$	1	3	1	0	0
$C2$	0	0	2	3	0
$C3$	0	0	0	1	4
$C4$	0	0	4	1	0
$C5$	0	3	2	0	0
$C6$	0	0	0	4	1

$$I_{B1} = \begin{bmatrix} 0.2 & 0.6 & 0.2 & 0 & 0 \\ 0 & 0 & 0.4 & 0.6 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0.8 & 0.2 & 0 \\ 0 & 0.6 & 0.4 & 0 & 0 \\ 0 & 0 & 0 & 0.8 & 0.2 \end{bmatrix}.$$

The expert score evaluations for other financing factors are conducted similarly, resulting in normalized single factor evaluation matrices for each factor.

(4) Fuzzy Comprehensive Evaluation

First level fuzzy comprehensive evaluation:

Single factor evaluation of bank loans:

$$\begin{aligned} R_{B1} &= W_{B1} \times I_{B1} \\ &= \begin{pmatrix} 0.2900 & 0.1145 & 0.0600 & 0.1466 & 0.2600 & 0.1289 \end{pmatrix} \begin{bmatrix} 0.2 & 0.6 & 0.2 & 0 & 0 \\ 0 & 0 & 0.4 & 0.6 & 0 \\ 0 & 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0.8 & 0.2 & 0 \\ 0 & 0.6 & 0.4 & 0 & 0 \\ 0 & 0 & 0 & 0.8 & 0.2 \end{bmatrix} \\ &= \begin{pmatrix} 0.06 & 0.33 & 0.33 & 0.21 & 0.07 \end{pmatrix} \end{aligned}$$

The single factor evaluations of other means of financing for green residential project are also obtained.

Single factor evaluation of issue bonds:

$$R_{B2} = W_{B2} \times I_{B2} = (0.25\ 0.40\ 0.25\ 0.06\ 0.04).$$

Single factor evaluation of private lending:

$$R_{B3} = W_{B3} \times I_{B3} = (0.10\ 0.20\ 0.40\ 0.20\ 0.10).$$

Single factor evaluation of pre sale:

$$R_{B4} = W_{B4} \times I_{B4} = (0.15\ 0.37\ 0.22\ 0.15\ 0.11).$$

Single factor evaluation of listing and financing:

$$R_{B5} = W_{B5} \times I_{B5} = (0.25\ 0.50\ 0.20\ 0.05\ 0).$$

Single factor evaluation of reorganized assets:

$$R_{B6} = W_{B6} \times I_{B6} = (0.20\ 0.55\ 0.18\ 0.07\ 0).$$

Second level fuzzy comprehensive evaluation:

$$I = \begin{bmatrix} 0.06 & 0.33 & 0.33 & 0.21 & 0.07 \\ 0.25 & 0.40 & 0.25 & 0.06 & 0.04 \\ 0.10 & 0.20 & 0.40 & 0.20 & 0.10 \\ 0.15 & 0.37 & 0.22 & 0.15 & 0.11 \\ 0.25 & 0.50 & 0.20 & 0.05 & 0 \\ 0.20 & 0.55 & 0.18 & 0.07 & 0 \end{bmatrix},$$

$$\begin{aligned} R &= W \times I \\ &= \begin{pmatrix} 0.4172 & 0.0576 & 0.0914 & 0.2338 & 0.1710 & 0.0290 \end{pmatrix} \begin{bmatrix} 0.06 & 0.33 & 0.33 & 0.21 & 0.07 \\ 0.25 & 0.40 & 0.25 & 0.06 & 0.04 \\ 0.10 & 0.20 & 0.40 & 0.20 & 0.10 \\ 0.15 & 0.37 & 0.22 & 0.15 & 0.11 \\ 0.25 & 0.50 & 0.20 & 0.05 & 0 \\ 0.20 & 0.55 & 0.18 & 0.07 & 0 \end{bmatrix} \\ &= \begin{pmatrix} 0.1322 & 0.3670 & 0.2795 & 0.1550 & 0.0663 \end{pmatrix}. \end{aligned}$$

Thus, for the Langshi green project financing risk evaluation, 13.22 % of the experts consider it in the category of great risk, 36.7 % significant risk, 27.95 % general risk, 15.5 % less risk, and 6.63 % little risk.

(5) Assessing the Level of Financing Risk

$$T = \frac{\sum_{i=1}^{5} v_i R_i}{\sum_{i=1}^{5} R_i} = \frac{1 \times 0.1322 + 2 \times 0.3670 + 3 \times 0.2795 + 4 \times 0.1550 + 5 \times 0.0663}{0.1322 + 0.3670 + 0.2795 + 0.1550 + 0.0663}$$
$$= 2.6562.$$

Table 132.1 indicates that the Langshi green blocks project in Chengdu is in the category of significant risk for financing.

132.4 Effective Management of Green Housing Financing Risk

132.4.1 Improving Policies and Regulations on the Financing of Green Buildings

The relevant laws and policies, such as the Construction Law and the Green Building Evaluation Standards, should be amended to include green buildings; in particular, the laws and policies governing the financing aspects of such projects should be established or enhanced. The goal is to provide guidance to standardized management of green building financing and thus lower the risks.

132.4.2 Focusing on the Primary Factors Influencing the Financing Risk of Green Building

Domestic green residential project financing risk factors are mainly policy and law, enterprise financial situation and corporate reputation factors. In the financing process of green housing, we should pay more attention to the major factors in order to devise effective responses to minimize the overall risk.

132.4.3 Introducing Policies for Effective Incentives and Create a Risk Sharing Mechanism

Under the existing financial system, the financing of green buildings in China is mainly based on debt financing, in which the green credit will take the largest share. At present, the overall scale of the green credit is relatively small, leading to high risks in green building financing as well as a lack of incentives for the banks to promote the green credit. Therefore, the introduction of effective incentive policy and the establishment of an effective risk sharing mechanism are crucial. Examples of such measures include capital regulation policy preferences, discount guarantee, which could reduce the financing cost of green buildings and lower loan risks.r An effective financing risk sharing mechanism is needed, similar to that of international finance organizations, where the risk of bank lending could be reduced through the establishment of local government funds.

132.4.4 Promoting the Development of Equity Financing Instruments and Risk Mitigation Tools

The financing structure of green buildings with debt instruments needs to be gradually changed, with the development of equity financing instruments and risk mitigation tools. The development of green risk mitigation tools, such as financing guarantees, financing lease, green asset securitization tools, will need to be emphasized.

132.5 Conclusions

Using the Chengdu Langshi green project as an example, this paper establishes the green residential financing risk index system, and conducts an analytical study of the financing risks associated with a green residential project. Based on both quantitative and qualitative analyses, this paper constructs the green residential financing risk evaluation model, which gives a clear evaluation criterion for green residential projects and effectively determines the financing risks of such projects. From the evaluation results, policy and legal factors have the greatest influence on the financing risks. The enterprises' own situations are also closely associated with the financing risks. The green building concept is a late development in China, with high construction cost and limited channels of financing, mainly through bank loans, real estate funds, and bonds. These means of financing are significantly affected by the national and local policies as well as other legal factors. The impact of enterprise financial situation, enterprise creditworthiness and management factors are substantial on green residential financing risks. The influence of macroeconomic factors on green residential financing is also significant. The rate of inflation, discretionary income and other factors on the financing are clearly important. In comparison, the industry competition is a relatively minor factor for green residential financing. Overall, the green residential project financing is determined to be of greater risk in Chengdu. Through the engineering case study with the Langshi green block project, financing risks are assessed employing the green residential project financing risk evaluation model presented in this paper, which could be useful for the future development of green communities and green cities.

Acknowledgments This paper is supported by Ministry of Housing and Urban-Rural Development science and technology project fund (project number: 2013-R1-4); Project supported by the Open Research Fund of Key Laboratory of Sichuan province (project number: szjj2012-033)

References

1. Ma X (2013) Discussion on investment and financing mode of green building. Ecol Econ 3:114–116
2. Shi Z (2007) Study on bidding decision model and fuzzy comprehensive evaluation based on artificial neural network. Master's thesis, School of Architecture and Engineering of Zhejiang University
3. Xiang L (2013) Logistics outsourcing risk evaluation and control based on ahp-fuzzy comprehensive evaluation approach. Enterp Econ 4:72–75

Chapter 133
Social Risk Assessment Index System by Composite Catastrophe Models: A Case Study in Contemporary China

Hong Li, Huifeng Zhang, Feng Wang and Ziqi Wang

Abstract Social risk refers to the possibility of a potential social unrest, and social conflicts and social damage states caused by uncertain factors in various areas. This uncertainty comes from ecology, social politics, economy, culture and other fields. Modern risks refer to dangers and insecurity happening in the systematic process of modernization. Threats of modern power led to the suspicion of all relevant consequences of modern globalization. In this paper, we investigate the problems of applying the catastrophe theory in social risk assessment by identifying potential indexes (known as crashes), which not only avoids the subjective assessment to some extent, but also gives an objective system to explore social risks.

Keywords Social risk · Quantitative analysis · Catastrophe theory · Mathematic model

133.1 Introduction

Although brilliant achievements have been registered in the economic construction of China, tough issues such as environmental pollution, ecological damage, extreme disparity between the rich and the poor have been brought by the highly compressed modernization process, the rapid development of urbanization and the accelerating social transformation [9]. Moreover, multiple symbiosis, interactive coupling, and

H. Li · H. Zhang · F. Wang
Seismological Bureau of Shandong Province, Jinan 250014,
People's Republic of China

H. Li
Emergency Management and Reconstruction in Post-disaster,
Sichuan University, Chengdu 610064, People's Republic of China

Z. Wang (✉)
Institute of Emergency Management and Reconstruction in Post-disaster,
Sichuan University, Chengdu 610064, People's Republic of China
e-mail: 1988229wzq@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_133

resonant social conflicts have also been triggered, threatening to the very peace of human daily life and causing too many complex social problems. An existing risk can often be found after severe damages [7]. In other words, we may decrease or prevent the immeasurable losses by assessing the risk before it evolved into a damage event to the society. However, first of all, we must be aware that the development of human society is always accompanied by social risks in a historical perspective [8]. As an old saying goes, "Risk is never zero, but it can be small". So, in consideration of the risk's uncertainty, it is an urgent need to deal with the various social risks so as to avoid the unimaginable destructiveness in the future.

A "risk" referring to "potential damage" (a damage that will not occur with certainties, but with a probability p where $0 < p < 1$) has been studied in many aspects in a range of different way [11]. To sum up, there are two ways to analyze the risk in the field of sociology: qualitative research and quantitative research. Primarily, in order to perceive risks, Beck studied the technical social risks from the perspective of ecology; Slovic studied its identification at the level of social psychology, suggesting that People respond to hazards according to their perceptions of risks they pose [1, 14]. Stephenet et al. [10] modified the qualitative risk assessment to help prevent waterborne outbreaks of cryptosporidiosis, and Menéndez et al. [5] analyzed the launched qualitative risk assessment to figure out the prevalence of hazards about Swiss dairy products. Demiret et al. [2] pointed out the limitation of P-I Tables, presenting a new tool to the analysis of risk through a practical application. From this point of view, depending on different kinds of concrete events, risks show different kinds of forms qualitatively without comparability to various dimensionalities, blocking the fusion of interdisciplinary research.

While scholars working on nature science prefer taking advantage of mathematical logic or modeling techniques to research the feasibility calculation, inducing the path of risk in quantization. Sahinoglu [5] provided a quantitative technique featured by an updated repository on vulnerabilities, threats, and countermeasures to calculate risk. Natakua et al. [17] found that, for an individual, social risks are related to gender, age, and education after interviewing 400 Russians living in Moscow or Tula in 2003. Liu [13] defined the risk as the "accidental loss" plus "uncertain measure of such loss", as well as discussed the tool of uncertain reliability analysis. Chandra and Khan [16] proposed a method to assess the availability risk in the era of IT. The quantified analysis at present is much more objective than qualitative method, giving us an intuitive feeling that risk may be small or big by a visual result from modeling algorithm; however, they were more or less based on the subjective judgments, the previous experience, experiments or simulation, which could not reflect the objective reality. These estimations are mainly taken from the perspective of probability theory, regardless of considering the social category of risk measurement, with too much subjectivity. Meanwhile, due to the ignorance of the characteristics of society such as complexity, disequilibrium, and polytrope, the whole society risk cannot be assessed comprehensively.

Society is full of sudden transformations and unpredictable divergences, which call for functions that are not differentiable, giving rise to a series of social conflicts, social disorders or social instability, so it is improper for us to investigate it just in normal way [19]. Catastrophe theory, a mathematical method for managing discontinuous and divergent phenomena, has been developed at present, which has been applied to a variety of fields, such as clinical psychology [19], refraction of traffic [8], economics [24], stock market [16], construction project dispute negotiation [4] and so forth. Even various mathematic models have been used for explaining the sudden changes or discontinuities of behaviors in nature or society [24]. To the best of our knowledge, one of the characteristics of the sociology study is that it cannot easily get a system dynamics equation on the basis of the known quantitative law. In terms of catastrophe theory to society, there is no need to know the inner disciplines of social system; it can make both certainties and uncertainties resolved at the same time; the social system can be described in a mathematic and quantitative way. So far, there are only a few papers on researching the empirical application of catastrophe theory in the social literature, not to mention the social risk index system. Hence, in this paper, we investigate the problem of applying the catastrophe theory to social risk assessment by identifying the potential indexes (known as crashes), which not only avoids the subjective assessment to some extent, but also gives an objective system to explore social risks [6].

Firstly, by using the Delphi method, the fire risk evaluation indices system for the buildings is developed. Secondly, by using the catastrophe theory, the model is introduced. Based on this assessment method, we can obtain the degree of social risk, and, by analyzing the estimation results, we can develop a scheme to guide the decision-makers to decrease the risk and then provide them with some appropriate countermeasures. Finally, the case study is given to show the effectiveness of the proposed theorems. The most significant aspect of this paper is to assess the uncertain risks quantificational through a less subjective method.

133.2 Catastrophe Models

Catastrophe theory is a special subset of mathematic tool developed by Thom's classification theorem, describing how continuous changes in independent control parameters can have abrupt and discontinuous effects on dependent variables, with properties of discontinuities directly without reference to any specific underlying mechanism [15]. Grasman et al. [20] further suggested that when catastrophe model is mathematically presented, empirical testing is possible. While the development of society is a continuous process in the whole human history, with so many sudden events breaking out intermittently, such as wars, group events, disasters etc., disturbing the consistent of the social risk. No matter the catastrophe theory or social risk, their common essential characteristic is uncertainty. Social risk, especially the man-made risk in the recent years, is the same with unexpected mutation in the catastrophe theory [12]. Further more, the incomputability is an arduous problem to sociology, political science or public administration, catastrophe theory can provide a new perspective to assess social risk and control public crisis. The main basis to apply catastrophe theory in social system is whether it has all of or some of the features

Zeeman pointed out. When exists, catastrophe theory can be used to fit the system, and then according to the numbers of controlling variables and status variables to select the corresponding catastrophe models.

133.2.1 Introduction to Typical Catastrophe Models

There are seven elementary catastrophe models by Thoms: fold catastrophe, cusp catastrophe, swallowtail catastrophe, butterfly catastrophe, hyperbolic umbilic catastrophe, elliptic umbilic catastrophe and parabolic umbilic catastrophe. For a basic tutorial on catastrophe model, the readers can learn from Woodcock and Davis. And there are several typical catastrophe models used commonly with at most four controlling variables are provided as follows:

The cusp catastrophe model:

$$f(x) = x^4 + ux^2 + vx. \tag{133.1}$$

You can see this model describes a three-dimensional response surface consisting of one dependent and two independent variables.The dynamics of the system is recorded in the vertical movements of the dependent variable as a result of the changes in its two control dimensions, where u and v are the two control dimensions and $F(X)$ represents the behavioral surface. And a specially designed program called $Cuspfit$[1] was used to analyze the cusp catastrophe models (133.2) and (133.3).

The coattail catastrophe model:

$$f(x) = x^5 + ux^3 + vx^2 + wx. \tag{133.2}$$

Another typical model, where u, v and w are the control dimensions.

The butterfly catastrophe model:

$$f(x) = x^6 + ux^4 + vx^3 + wx^2 + tx, \tag{133.3}$$

where $F(X)$ is the potential function of x; u, v, w, t are the controlling variables of the state variables.

As you can see above, when evaluating the objectives, we can choose the cusp catastrophe model, the coattail catastrophe model, or the butterfly catastrophe model, respectively by the number of controlling variables (do not take the variables more than four into consideration). Furthermore, generally the more important controlling variables are written in the frontartificially, which is an inevitable limitation for the present study. However, we will minimize this subjectivity as far as possible by random analysis.

133.2.2 The Process of Fuzzy Catastrophe Methods

After the above introduction, we'll conduct how to combine the social risks with the catastrophe theory to build an index system. There are mainly two obvious comparative advantages for the catastrophe regression method in the following respects: on one hand, it does not use any weight, only need to arrange indicators according to the importance of the inherent logic relationship among indicators, which avoids making the subjectivity of the artificial weight evaluation in a very large limit; on the other hand, as a technological approach that combine qualitative analysis and quantitative analysis together, it is not only suitable to judge whether the indictor is suitable for the assessment of risk, but also provide models to calculate out the concrete number value of social risk to make a comparison in different years. However, there are some fuzzy elements should be taken in account during the process [23].

For a real system, how to confirm the numbers of controlling variables to affect the system is complex, especially for the large complicated systems, like earthquakes and volcanic eruptions. The controlling variables which can influence the social system are uncertainty with the limitation of human cognition [4].

Though we have got accurate influencing elements, how to get the exact potential function, which can describe the relationship between controlling variables in the system is uncertain.

Furthermore, basing on the first two assumptions above, there is an error which comes from the outside controlling variables, while human factors added the uncertainty [22]. So we should take the fuzzy factors into consideration to expand the degree of accuracy. Here are the steps we develop the index system and how to deal with it.

Step 1. Establish evaluation index system by Delphi.
A number of experts were invited in the case of mutual isolation to fill in the questionnaire about social risk in several rounds. Then, we get the consistent indicators which the experts mostly agree with.

Step 2. Choose the catastrophe types and develop the normalized formula.
It can not take use of bifurcation set equation, for the state variables and controlling variables do not have a unified value range, and the same with fuzzy membership number between 0 and 1. Therefore, normalization should be developed at first, to limit the value range of state and controlling variables into (0, 1). The normalizing formulas of the typical catastrophe models can be obtained:

$$x_u = u^{1/2}, x_v = v^{1/3}, \tag{133.4}$$

$$x_u = u^{1/2}, x_v = v^{1/3}, x_w = w^{1/4}, \tag{133.5}$$

$$x_u = u^{1/2}, x_v = v^{1/3}, x_w = w^{1/4}, x_t = t^{1/5}. \tag{133.6}$$

Step 3. The evaluation index of quantitative classification.

Step 4. Data preprocessing.
After using the normalized formulas, a plurality of control variables will

be calculated into several state variable values, which exists dimensional difference in the indices. So we can adopt the "mini-max" or average principle to eliminate such kind of difference impact in order to find out the final value. The formula is as follows:

$$\tilde{X}^j = \frac{X^j - X^j_{\min}}{X^j_{\max} - X^j_{\min}}, \tag{133.7}$$

$$\tilde{X}^j = \frac{X^j_{\max} - X^j}{X^j_{\max} - X^j_{\min}}. \tag{133.8}$$

Step 5. Indicators of integration (FIg. 133.1).

Then, the steps of the method is developed as follows:

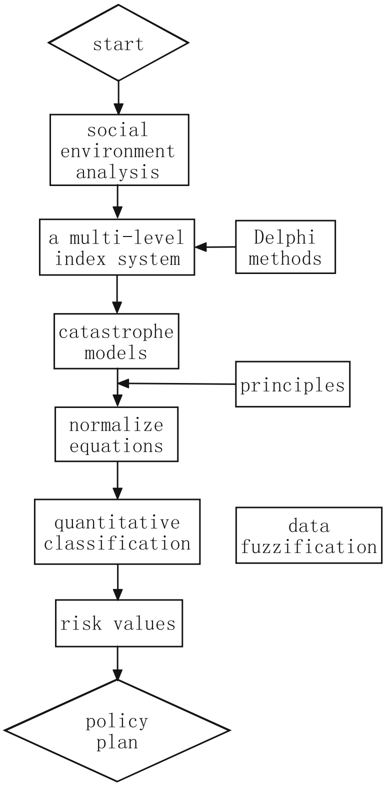


Fig. 133.1 The steps of the catastrophe progression method

133.3 Evaluation Index System

Social risk is a foreboding to the stand or fall development of society in some extent. It can give a forecast about social steady. Many scholars have given opinions about how stable is stability for the society [21]. In 1961, Tiryakian provided three indictors to measure the social instability: (1) the increase of urban development; (2) the chaos and extensions of sex, as well as the disappeared social limitations; (3) the great increase of non-institutionalized religious phenomena. In 1976, Estes and Morgan thought that the degree of social instability for a country can be assessed from six aspects. And Estes pointed that instability could be highest in the following situations, such as the decrease of available social resource, unstable politics, the more serious to not meet human needs. We should take these factors into account, and combine with the situation in China nowadays to develop an index system.

133.3.1 Establishment of Evaluation Index System

Before we started to develop the indicator system, taking the current situation of China into consideration, while analyze the social environment and historical events, after several rounds of anonymous assessment, we selected four parts of indices in order to assess the risk in generally. We choose the areas of economy, society, polity and culture. Economy as the most important barometer to the whole society should be placed at first. The factors that conceal social risks mainly include the following aspects in Table 133.1:

(1) Economic indices A, including the rate of unemployment $A1$, absolute poverty $A2$, and inflation $A3$, etc.; economy shows a country's strength to a large extent;
(2) Social indices B, including crime rate $B1$, divorce rate $B2$, population flow rate $B3$, suicide rate $B4$, etc.;
(3) Political indices C, including cadres corruption $C1$, incidence of mass incidents $C2$, collective demonstrations $C3$, etc.;
(4) Cultural indices D, including happiness index $D1$, social satisfaction $D2$,etc; which with the improvement of living standard, people have higher requirement about the quality of life, so combining with the formulation of harmonious society here we choose happiness index and social satisfaction to assess the current situation about Chinese life.

133.4 Applied Analysis

Tibet Autonomous Region, which located in the western of China, founded in September 1, 1965, is an inalienable part of China since ancient times. It has abundant resources, including but not limit with nature resources, cultural resources, location

Table 133.1 The index system of social risk

Target layer	Rule layer	Factors layer
Social risk estimation	Economic indices	Unemployment rate (%)
		Absolute poverty rate (%)
		Inflation rate (%)
	Social indices	Crime rate (%)
		Divorce rate (%)
		Population flow rate (%)
		Suicide rate (%)
	Political indices	Cadres corruption
		Incidence of mass incidents (%)
		Collective demonstrations (%)
	Cultural indices	Happiness
		Satisfaction about economy and society

resources, but also too many concessional policy advantages. However, because of geopolitical differences in the quality of cultivated land resource, far away from the economic center, the poor transportation, and so on, the poverty is caused and aggravated in the ethnic minority areas, and further more bring so many social problems, which puzzled Tibet heavily [3]. But those mentioned above are inherent objective factors, while on behalf of the feudal serfowner remnants of the dalai clique promoted the Tibet independence by taking advantage of religious issues, produced so many chaos like self-immolation cases in Aba, Sichuanon Mar, 2013 that destructed the social normal order into the climax [8]. The detractors who take use of the current potential risks make such disturbing events blocking the national unity and reunification of the motherland. And by the shackles of traditional ideas, the nature resources have not changed into economic advantages, and hindering production potential has not been full play. So, taking the internal and external factors into consideration, it is really necessary to make an assessment of social risk about Tibet to prevent such mass events [17].

After consulting China Statistical Yearbook and Tibet Statistical Yearbook, we can get a numerical test from 2008 to 2013. We should consider the development of Tibet agriculture and its related industries as equally important position with industry. Seeking a sustainable way develop the growing economy basing on the husbandry and its related industry, to construct a new industrial structure to promote the development of regional economy [16]. Always adhere to safeguard the motherland's peaceful reunification unswervingly. Endeavour to the national reunification in maximize, and support the economic development in Tibet, and promote and improve the living standard. In this section, the collected parameter data from the Lushan emergency response headquarters is used with model and the results were shown in Table 133.2.

Table 133.2 Risk probability of the sample

Areas	Economic indices (%)	Social indices (%)	Political indices (%)	Cultural indices (%)	Total (%)
Tibet	14.33	10.14	25.54	28.65	78.66
Sichuan	15.32	13.43	19.43	15.98	64.16
Hubei	11.23	15.65	8.21	7.54	42.63
Shandong	6.54	7.58	9.89	7.33	31.34

Results and discussions, and from the analysis above, we can find that the risk is a little high for the Tibet with higher social risk, the much more social events will happen to disturb the society. We can decrease the risk from the different levels of index system. In the economy, the supportive policies are still necessary, not only financial supports or resource developments, but also the talent introduction and communication with other districts [11]. Then, about culture, we should respect the faith of Tibetans, and give them the real equal and understanding. Last but not at least, keep constant attention on Tibetan society, avoid riot take place again [18].

In order to assess the potential social risks, we used catastrophe models to calculate the value of risks, and make a warning in 2013, while make a trend diagram for recent years. We found that social risk is increasing. With the development of all social aspects, risks, which do not appear before came out.

133.5 Conclusion

The reality of limited government, the compound management complexity requirements accordingly risk, namely to strengthen cooperation and common governance between the government and society, the transformation of government management from the control of the risk for mobilizing all social forces, jointly cope with risks, within the scope of the whole society to build up crisis prevention, preparation, processing, and restore the comprehensive crisis management system. Risk cognition of the subjective understanding of the risk, namely under the factors of uncertainty, people whether to risk the rational understanding and the appropriate reaction, is to determine the government and the public can form effective risk communication, and agreed with the public, to win together with the important factors. Public safety as a kind of public goods, the government is not the only producer of public goods, the government—the market—the compound in the process of governance, civil society in the condition of multiple main body participation, the public crisis governance dilemma is largely a reflection of social crisis of trust and cooperation.

Acknowledgments We are very appreciated for the support from Science for Earthquake Resilience (Grant XH14032Y) and Sichuan University both in finance and in spirit. Further, we would like to thank all of the referees for their insightful comments and suggestions to improve this paper.

References

1. Beck U (1992) Risk society: towards a new modernity, vol 17. Sage, Thousand Oaks
2. Chipman ML (1982) The role of exposure, experience and demerit point levels in the risk of collision. Accid Anal Prev 14(6):475–483
3. Dari-Mattiacci G, Faure MG (2015) The economics of disaster relief. Law Policy 37(3):180–208
4. Fares ARF, Abou-Bakr EA et al (2012) Economics of insurance against natural catastrophes: Over-burdened arab insurers. Rev Econ Financ 2:95–105
5. Finkel AM (2002) The joy before cooking: preparing ourselves to write a risk research recipe. Hum Ecol Risk Assess 8(6):1203–1221
6. Gsottbauer E, van den Bergh JC (2011) Environmental policy theory given bounded rationality and other-regarding preferences. Environ Resour Econ 49(2):263–304
7. Hilty LM, Som C, Köhler A (2004) Assessing the human, social, and environmental risks of pervasive computing. Hum Ecol Risk Assess 10(5):853–874
8. Joas H (1988) Pragmatism and social theory. University of Chicago Press, Chicago
9. Kaplan S, Garrick BJ (1981) On the quantitative definition of risk. Risk Anal 1(1):11–27
10. Klinke A, Renn O (2002) A new approach to risk evaluation and management: Risk-based, precaution-based, and discourse-based strategies. Risk Anal 22(6):1071–1094
11. Korstanje ME (2009) Towards a new modernity. J Disaster Risk Stud (2):147
12. Kousky C, Luttmer EF, Zeckhauser RJ (2006) Private investment and government protection. J Risk Uncertain 33(1–2):73–100
13. Liu B (2010) Uncertain risk analysis and uncertain reliability analysis. J Uncertain Syst 4(3):163–170
14. McDonald S, Berzano M et al (2011) Qualitative risk assessment of surface water contamination with cryptosporidium sp. oocysts: A case study of three agricultural catchments. Human and Ecological Risk Assessment: An. Int J 17(4):813–825
15. Pryce G, Chen Y, Galster G (2011) The impact of floods on house prices: an imperfect information approach with myopia and amnesia. Hous Stud 26(02):259–279
16. Rodionova N, Vinsonneau G et al (2009) Societal risk perception in present day Russia. Hum Ecol Risk Assess 15(2):388–400
17. Sahinoglu M (2005) Security meter: A practical decision-tree model to quantify risk. IEEE Secur Priv 3:18–24
18. Schad M, John J (2012) Towards a social discount rate for the economic evaluation of health technologies in germany: an exploratory analysis. Eur J Health Econ 13(2):127–144
19. Scott DW (1985) Catastrophe theory applications in clinical psychology: a review. Curr Psycho 4(1):69–86
20. Viscusi WK, Zeckhauser RJ (2006) National survey evidence on disasters and relief: risk beliefs, self-interest, and compassion. J Risk Uncertain 33(1–2):13–36
21. Worthington A, Valadkhani A (2004) Measuring the impact of natural disasters on capital markets: an empirical application using intervention analysis. Appl Econ 36(19):2177–2186
22. Yamamura E (2014) Corruption and perceived risk: a case of the 2011 fukushima disaster. Int J Soc Econ 41(11):1156–1170
23. Yamamura E et al (2011) How does corruption influence perceptions of the risk of nuclear accidents? cross-country analysis after the 2011 fukushima disaster in Japan. MPRA Paper 31708
24. Zeckhauser R (1996) The economics of catastrophes. J Risk Uncertain 12(2–3):113–140

Chapter 134
Technology Innovation-Oriented Complex Product Systems R&D Investment and Financing Risk Management: An Integrated Review

Lei Xu and Shiyun Tang

Abstract Increasingly software and embedded intelligence products are integrated in various industrial systems to promote the continuous deepening of the industry 4.0, especially for the complex product systems (CPS). Definitely, the development of CPS is driven by technology innovation-oriented research and development (R&D). Besides, investment and financing have been widely acknowledged as a crucial link in R&D to ensure and sustain the development of CPS and even industry 4.0. However, CPS R&D activities are characterized by complexity and high uncertainty so that risks of the investment and financing are more complex and changeable. Thus, effective risk management for CPS R&D is becoming particularly important. Risk management is a process of determining what risks exist in an investment and then handling those risks in the best-suited way. Therefore, the paper aims at summarizing and analyzing research status for different objects in existing literatures about investment and financing risk management of CPS R&D. And studies are mainly from three aspects: risk assessment, risk early warning, management and control. Based on the past literatures, the future research directions have been proposed and it might be able to serve as a preliminary guide for investment and financing risk management of CPS R&D.

Keywords CPS · R&D · Investment · Financing · Risk management

134.1 Introduction

In retrospective industrial revolutions always lead to a significant increase in productivity. Digitally networked and data-intensive are the main attributes of a smarter production, the so called industry 4.0 [4]. The core of Industry 4.0 is intelligent

L. Xu (✉) · S. Tang
School of Economics, Xihua University, Chengdu 610039, People's Republic of China
e-mail: leihsu@163.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_134

plant. Intelligent plant is a high energy efficiency plant, which is based on high-tech, adaptable, ergonomic production line. Its goal is integrate customers and business partners, also can manufacture and assemble customized products. With the advance of industry 4.0, increasingly software and embedded intelligence are integrated in industrial products and systems appear in the eyes of the world and complex product systems (CPS) are the most representative. CPS is customized, one-off or small batched capital goods items, which are high in complexity and value. Large complex product development includes ships, planes, power plants, etc. It is characterized by high manufacturing costs, large physical size, uniqueness, high investment costs, long manufacturing life cycle and engineering complexity in terms of design features, configuration and performance [15, 34]. CPS is also called large-scale technology system, characterized by customized, interconnected subsystems, high cost, produced in low volume, require a breadth and depth of knowledge and skills, involve multiple collaborators, and have continuous integration with client and supplier [29]. CPS is driven by technology innovation. Because the goal of innovation is positive change and to make something better. Innovation leading to increased productivity is the fundamental source of increasing wealth in an economy [1]. Schumpeter [26] put technological change and innovation at the center of the capitalist market economy. Moreover, R&D is critical input for innovation and is thus a main driver of economic growth [8]. More smart factories focus mostly on it.

A new product development represents a technical, organizational and financial challenge for companies [11]. Due to CPS R&D activities are characterized by high uncertainty, asymmetric information and high costs of transacting that information [43], risk can be divided into 5 categories: (1) Investment and financing risk; (2) Market risk; (3) Policy risk; (4) Management risk; (5) Production risk. It has been widely acknowledged that managing risk is a crucial element of technological innovation [14]. Particularly, the impact of research and development (R&D) investment on firm value has been the subject of extensive theoretical and empirical research. There is a large literature showing R&D investment creates value for firms [43]. Effective investments can improve the efficiency of production resources using, and make an intensive economic growth of the sector as well as to increase the production capacity of enterprises [37]. Countries should invest in R&D in order to ensure and sustain economic growth and development in this system [15]. Hence the risk management of investment and financing is particularly important in manufacturing industry. Risk management is a process of determining what risks exist in an investment and then handling those risks in the best-suited way [22]. China is a major manufacturing country in the world, characterized by extensive growth with at the expense of resources and labor forces for a long time. However, China has not become a powerful manufacturing country. China's manufacturing industry is faced with challenges of restructuring and upgrading. The analysis and methods of risk management proposed in this paper could serve as a guide for the development of manufacturing industry on theory and practice in China [25].

In this paper, it was reviewed that investment and financing risk management of technology innovation-oriented CPS R&D. The rest of this paper is organized as follows: In Sect. 134.2, according to the literatures, we subdivide the subject problem involved. In Sect. 134.3, we describe in detail about investment and financing risk management related literature. In Sect. 134.4, we provide critical comments and recommendations for future research. The paper ends with a summary of the key findings and conclusions.

134.2 Research Issues

It is widely recognized that innovation risk is one of the most important influencing factors of technology innovation and development, particularly on new and emerging technologies [7]. In fact, the effect of risk management is more pronounced in the case of investments and financing in CPS R&D. Risk management includes a lot of aspects. According to the vast literature on investment and financing of risk management, investment and financing risk management mainly includes three aspects. In every aspect, the literatures propose appropriate solutions for the objects. In order to show the research status about investment and financing risk management, we subdivide the related literatures in the Table 134.1.

As it can be seen in Table 134.1, investment and financing risk management mainly includes three aspects: (1) Risk assessment. It is mainly used to assess risk and establish risk assessment system. Data mining methods are often used for credit risk assessment. Besides, most studies have been improvement of existing methods for investment and financing risk assessment. (2) Risk early warning. In the literatures the early warning systems have been presented, which are using for predicting the success level and reducing risk. In most studies, financial early warning systems are usually based on data mining methods. (3) Management and control. It refers to find solutions to control risks. Scholars propose appropriate methods for different objects and validate the accuracy of the method. Next, according to the table of contents, we describe in detail related literatures.

134.3 Literature Review

According to the Sect. 134.2, investment and financing risk management of CPS R&D mainly includes three aspects: risk assessment, risk early warning and management and control. This section describes the related literature detailed. The concept diagram of the overview for the research issue is as follows (Fig. 134.1).

134.3.1 Risk Assessment

Risk assessment is important initial steps that may contribute to future project management success. A poor quality risk assessment process may compromises the

Table 134.1 Related literatures of investment and financing risk management

Main issue	Related researches	Objects	Methods	
Investment and financing risk management of CPS R&D	Risk assessment	Financing	Questionnaire report	
		Investment project	Monte carlo method	
			Competition model	
			Cash flows	
			Data mining	Neural network
		Credit		Decision tree
				Logistic regression
				MCLP
				SVM
		Finance	VaR	Parametric
				Nonparametric
			Failure mode and effects analysis	
		Investment decision	VaR	
			CVaR	
	Risk early warning	Finance	Data mining	Feature selection techniques
				CHAID algorithm method
				SVM
				Logistic model
			Information fusions	Dempster shafer theory
				Bayesian theory
			Stepwise regression method	
			Logit model	
		Credit	KMV model	
		Stock market	Market instability index	

(continued)

Table 134.1 (continued)

Main issue	Related researches	Objects	Methods	
	Management and control	Collective investment	M.H. Markowitz's selective model	
		R&D project	Real options models	
		Investment level	ALARP process model	
		Financing	Hybrid bond	
		Investment intensity	CIMDO and GDFM	
		Investment decision	Behavioural and neuroeconomic approach	
			Statistical analysis	
		Stock market	EWMA method	
		Finance	Risk allocation	
		Investment scale	Two-stage DEA	

project and will turn risk management more demanding [19]. Some scholars focus on the risk assessment of investment risk management. In investment project, traditional methods are used for evaluating investment projects and dealt with their relation to risk, with the inclusion of risk in the evaluation of economic efficiency [3]. Platon [33] and Olaru [32] used Monte Carlo Method to assessment environmental risks in investment. The two papers pointed out that environmental risk prediction provides important information regarding the risks of investment projects by example. The paper 19 indicated the determination of the degree of uncertainty in achieving the proposed safety performance indicators, which had a positive impact on project objectives [35]. Ferdan [12] presented a complex methodology towards investment risk quantification in a waste-to-energy project. It is based on an innovative computational approach involving complex simulations of future competitive environments. The results of this work support decision-making processes. Luo [28] established a risk evaluation index system and financing model. Model application data after investigating, and get the risk synthesis value, then judge the risk level of the project. VaR model is used for estimating the level of risk. The model includes two aspects; parametric methods and nonparametric methods [13, 20]. The paper 24 presented Failure Mode and Effects Analysis to evaluate finance risk and predict different types of changes. It is easier to make decisions on future steps in solving the finance risk [31]. Hong [16] used Conditional Value at Risk measurement techniques to establish investment management model for investment decisions and demonstrated the validity of model by a case.

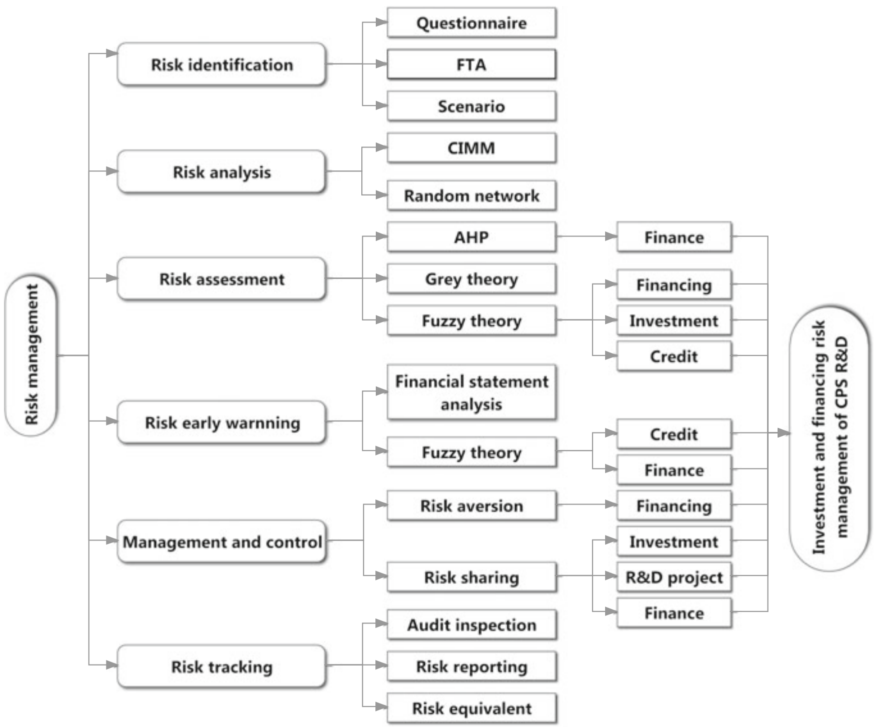


Fig. 134.1 Concept diagram of the overview for the research issue

Besides, in terms of methodology, data mining has been widely applied to make prediction for risk management, and they often obtain a good result. Data mining refers to the extraction of useful patterns or rules from a large database. The data mining process involves identifying the business problem and data mining goal, retrieving the database needed, and using data mining techniques to analyze the data with the final aim of achieving important results for making strategic decisions [5]. Wang [47] raises the variable-structure BP neural network model for investment risk evaluation index system. The results suggest that the prediction accuracy is very high. Credit risk is an important part of investment and financing. Some scholars used data mining methods of Logistic regression, MCLP, decision tree and SVM for credit risk assessment and obtained an effective evaluation model [10, 17, 30, 45].

134.3.2 Risk Early Warning

An early warning is a method which is using for predicting the success level, probable anomalies and is reducing crisis risk of cases, affairs transactions, systems, phenomena, firms and people. Data mining is a common technique in early warning system. Zhang [44] used information fusion technique to build a finance early-warning model based on data mining methods, which can integrate the respective strengths from different data mining methods to improve the prediction accuracy rate provides a better support for decision. CHAID algorithm has been used for development of early warning system for financial risk detection and risk reduction [21]. Zhou [46] investigated the performance of different financial distress prediction models with features selection approaches based on domain knowledge or data mining techniques. The empirical results show that the prediction performance of CFDPM with the feature subset selected by data mining can be as good as that by domain knowledge. The paper 59 develops a new financial early warning logit model which has better predictive accuracy than existing ones [24]. In financing, Chen [9] proposed a model based on the original KMV model with tunable parameters to measure the credit risk of Chinese listed SMEs. The validity of the model is verified by multiple tests. The paper 61 used stepwise regression method to establish the financial systemic risk best predict equation, thus set up the reasonable and practical financial systemic risk early-warning index system [27]. Yoon [42] proposed to utilize market instability index (MII) and stepwise risk warning levels that can diagnose the current instability of the stock market to foretell how the current stock market will proceed in advance.

134.3.3 Management and Control

The nature of project investment and financing is risk management. The management of this section is a narrow sense of risk management, which refers to build model for risk management. Methods of risk management are various. Bhattacharya [6] proposed to simulation optimization for portfolio risk analysis. Markowitz selective model is proposed to optimization of the investment portfolio [36]. The paper 5 used a behavioural and neuroeconomic approach for investment decision making risk [38]. Yakob [41] identified the exogenous variables of risk and investment management efficiency by using a two-stage data envelopment analysis method. The results showed that size is also a significant indicator for risk management efficiency. The utility-based methods are used to derive the value of an R&D project with unhedgeable technical uncertainty [39]. Jin's [18] study applies to investment funds a novel frame work which combines marginal probabilities of distress estimated from a structural credit risk model with the consistent information multivariate density optimization methodology and the generalized dynamic factor model. ALARP process model focuses on investment levels and stimulates the generation of alternative risk- reducing measures. They concluded that the extended model provides a valuable decision support tool if properly implemented [2]. Lee [23] presented a new financing instrument, called hybrid bond, to build renewable energy projects. A hypothetical example illustrates how a hybrid bond is used to finance renewable energy projects and how a hybrid bond is used to handle major uncertainties. Wu [40] pointed out risk allocation is a key aspects show that the nature of project finance is risk allocation of project finance while wrong risk sharing is a dominant cause of disputes. Effective risk allocation can improve project performances. They putted forward a rule and method of risk allocation in project finance.

134.4 Analysis and Future Work

Investment and financing of CPS R&D is faced with technical uncertainty. Hence it is significant for investment and financing of CPS R&D to manage risk. The past literatures have been provided important theory evidence and experimental evidence for solving the problem. In this section, we analyze the research status of above and present some coarse prospects of future research directions.

In risk assessment, using of Monte Carlo Method to assessment environmental risks in investment is relatively easy to perform and provides important information regarding the risks of investment projects. Data mining method can improve accuracy of credit risk assessment, which has a positive impact on investment and financing. The variable-structure BP neural network model is used to investment project risk assessment. It can effectively solve the contradiction between the operation accuracy and operation efficiency of the traditional neural network algorithm. The VaR and CVaR model are approaches and algorithms risk quantification. They also can achieve good results for estimating the level of risk. NERUDA tool is used for a complex methodology based on the repetitive, which is novel.

The most important of the early warning system is risk prediction accuracy rate. From the above, data mining and information fusion are widely used in risk early warning. By the application of this technique of analysis, the condition and possible risks of investment and financing can be identified with quantity and the risk prediction accuracy rate is improved. Besides, stepwise regression method is propitious to set up risk early-warning index system. The warning levels derived by MII can effectively diagnose the current instability of the stock market. And the possible improvement by using less number of sub-periods in unstable period will be investigated. The logit model is a high accuracy rate of prediction model for efficiency. But it has no certain conclusion for some companies. It may be possible that make a combination which enables efficiency indicators to enter logit models as explanatory indicators. Credit risk accurate rate is improved by KMV model. Building the most optimum function of two volatilities for listed SMEs can get better results. More data should be collected to verify the results produced by the model.

In management and control, effective risk allocation can improve project performances for financing. Hybrid bond which is a financing instrument mentioned in above also can reduce financing risk. Not only can it financing, but also reduce risk. The future research should assess the sensitivity study and dynamic asset allocation of the hybrid bond. In investment, simulation optimization model is good for portfolio risk minimization. If a comprehensive risk analysis is used in research, the results will be better. Markowitz's model is used for investment portfolio to minimize the risk. A behavioural and neuroeconomic approach reduces the risk of investment decision. In R&D investment, the real options approach takes into account the time value of the project investment and the value of the flexible value and the price of uncertainty in the future.

Based on the past literatures, the coarse prospects of future research directions have been made. We should pay close attention to effective risk management for investment and financing of CPS R&D. Firstly, find the risk factors and reasonable methods. Risk identification, risk assessment, and risk management have many commonly used methods. The correct and reasonable selection from them is an important precondition to ensure risk management realizing successfully. Secondly, improve the accuracy of risk prediction. One time process cannot often obtain a well support decision, and one single method has its weakness for classification [33], we can find the correspondences between methods and reasonable application.

134.5 Conclusion

This paper aims at summarizing the research state of investment and financing risk management to promote CPS R&D. According to the systematic literatures review, we understand the existing risk management methods of investment and financing. Risk management methods are diverse and each method has advantages to solve problem. However, multiple and complicated factors are involved when managing CPS R&D risks, and seeking a new method suitable for investment and financing risk management of CPS R&D is of significance. At present, we are in a big data Era. Information fusion and Data mining are used for dealing with mass data. Their principles are different, but the functions are complementary. They may solve the problem of investment and financing risk management of CPS R&D and get good result. This is author of the next research direction.

Acknowledgments This work is supported by a Program of [National Natural Science Foundation of China] under Grant [Number 71401136]; [China Postdoctoral Science Foundation] under Grant [Number2014M552375]. The authors are indebted to the editors and re-viewers for the valuable comments and suggestions.

References

1. Akcali BY, Sismanoglu E (2015) Innovation and the effect of research and development (R&D) expenditure on growth in some developing and developed countries. Procedia-Soc Behav Sci 195:768–775
2. Aven T, Hiriart Y (2011) The use of a basic safety investment model in a practical risk management context. Reliab Eng Syst Saf 96(11):1421–1425
3. Bartošová V, Majerčák P, Hrašková D (2015) Taking risk into account in the evaluation of economic efficiency of investment projects: traditional methods. Procedia Econ Financ 24:68–75

4. Bauer W, Hämmerle M et al (2015) Transforming to a hyper-connected society and economy-towards an "industry 4.0". Procedia Manuf 3:417–424
5. Berry MJ, Linoff G (1997) Data mining techniques: for marketing, sales, and customer support. Wiley, New York
6. Bhattacharya A, Kojima S (2012) Power sector investment risk and renewable energy: a japanese case study using portfolio risk optimization method. Energy Policy 40:69–80
7. Bi K, Huang P, Ye H (2015) Risk identification, evaluation and response of low-carbon technological innovation under the global value chain: A case of the chinese manufacturing industry. Technol Forecast Soc Chang 100:238–248
8. Brown JR, Martinsson G, Petersen BC (2012) Do financing constraints matter for R&D? Eur Econ Rev 56(8):1512–1529
9. Chen X, Wang X, Wu DD (2010) Credit risk measurement and early warning of SMES: an empirical study of listed smes in China. Decis Support Syst 49(3):301–310
10. Chen W, Xiang G et al (2012) Credit risk evaluation by hybrid data mining technique. Syst Eng Procedia 3:194–200
11. Elstner S, Krause D (2014) Methodical approach for consideration of RAMP-up risks in the product development of complex products. Procedia CIRP 20:20–25
12. Ferdan T, Šomplák R et al (2015) A waste-to-energy project: a complex approach towards the assessment of investment risks. Appl Therm Eng 89:1127–1136
13. Frajtová-Michalíková K, Klieštik T, Musa H (2015) Comparison of nonparametric methods for estimating the level of risk in finance. Procedia Econ Financ 24:228–236
14. Hall J, Bachor V, Matos S (2014) The impact of stakeholder heterogeneity on risk perceptions in technological innovation. Technovation 34(8):410–419
15. Hubel H, Colquhoun G (2001) A reference architecture for engineering data control (EDC) in capital plant manufacture. Comput Indus 46(2):149–165
16. Hx Sun, Zf Tan (2012) Models of risk measurement and control in power generation investment. Syst Eng Procedia 3:125–131
17. Hui L, Li S, Zhou Z (2013) The model and empirical research of application scoring based on data mining methods. Procedia Comput Sci 17:911–918
18. Jin X, De Simone FN (2014) A framework for tracking changes in the intensity of investment funds' systemic risk. J Empir Financ 29:343–368
19. Junkes MB, Tereso AP, Afonso PS (2015) The importance of risk assessment in the context of investment project management: a case study. Procedia Comput Sci 64:902–910
20. Klieštik T, Musa H, Frajtová-Michalíková K (2015) Parametric methods for estimating the level of risk in finance. Procedia Econ Financ 24:322–330
21. Koyuncugil AS, Ozgulbas N (2012) Financial early warning system model and data mining application for risk detection. Expert Syst Appl 39(6):6238–6253
22. Kushalappas S, Kundar S (2014) Risk management through efficient portfolios. Int J Appl Financ Manage Perspect 3(2):969
23. Lee CW, Zhong J (2015) Financing and risk management of renewable energy projects with a hybrid bond. Renew Energy 75:779–787
24. Li S, Wang S (2014) A financial early warning logit model and its efficiency verification approach. Knowl-Based Syst 70:78–87
25. Lia X (2011) Upgrading of China's manufacturing industry: Two-sector analysis based on the facilitation of producer services. Procedia Environ Sci 10:307–312
26. Limanlı Ö (2015) Determinants of R&D investment decision in Turkey. Procedia-Soc Behav Sci 195:759–767
27. Liu D, Zhou G et al (2013) The regional financial risk early-warning model integrating the regression of lagging factors. Appl Math Inf Sci 7(3):1035
28. Luo FZ, Gao HY (2011) The risk assessment model of BT construction engineering project financing. Syst Eng Procedia 1:169–173
29. Magnaye R, Sauser B et al (2014) Earned readiness management for scheduling, monitoring and evaluating the development of complex product systems. Int J Proj Manage 32(7):1246–1259

30. Mandala IGNN, Nawangpalupi CB, Praktikto FR (2012) Assessing credit risk: an application of data mining in a rural bank. Procedia Econ Financ 4:406–412
31. Nikolić DM, Jednak S et al (2011) Project finance risk evaluation of the electric power industry of Serbia. Energy Policy 39(10):6168–6177
32. Olaru M, Şandru M, Pirnea IC (2014) Monte carlo method application for environmental risks impact assessment in investment projects. Procedia-Soc Behav Sci 109:940–943
33. Platon V, Constantinescu A (2014) Monte carlo method in risk analysis for investment projects. Procedia Econ Financ 15:393–400
34. Rouibah K (2003) Managing concurrent engineering across company borders: a case study. In: Proceedings of the 36th annual Hawaii international conference on system sciences, 2003, IEEE, p 11
35. Rudnik K, Deptuła AM (2015) System with probabilistic fuzzy knowledge base and parametric inference operators in risk assessment of innovative projects. Expert Syst Appl 42(17):6365–6379
36. Spuchl'akova E, Michalikova KF, Misankova M (2015) Risk of the collective investment and investment portfolio. Procedia Econ Financ 26:167–173
37. Sujova A, Hlavackova P, Safarik D (2015) Analysis of investment effectiveness in the wood processing industry of the czech republic. Procedia Econ Financ 26:382–388
38. Virlics A (2013) Investment decision making and risk. Procedia Econ Financ 6:169–177
39. Whalley AE (2011) Optimal r&d investment for a risk-averse entrepreneur. J Econ Dyn Control 35(4):413–429
40. Wu SF, Wei XP (2009) The rule and method of risk allocation in project finance. Procedia Earth Planetary Sci 1(1):1757–1763
41. Yakob R, Yusop Z et al (2014) Two-stage dea method in identifying the exogenous factors of insurers' risk and investment management efficiency. Sains Malaysiana 43(9):1439–1450
42. Yoon W, Park K (2014) A study on the market instability index and risk warning levels in early warning system for economic crisis. Digit Signal Process 29:35–44
43. Zhang W (2015) R&D investment and distress risk. J Empir Financ 32:94–114
44. Zhang L, Zhang L, Teng W, Chen Y (2013) Based on information fusion technique with data mining in the application of finance early-warning. Procedia Comput Sci 17:695–703
45. Zhang L, Hu H, Zhang D (2015) A credit risk assessment model based on svm for small and medium enterprises in supply chain finance. Financi Innov 1(1):1–21
46. Zhou L, Lu D, Fujita H (2015) The performance of corporate financial distress prediction models with features selection guided by domain knowledge and data mining approaches. Knowl-Based Syst 85:52–61
47. Zuogong W, Huiyang L, Yuanhua J (2013) A neural network model for expressway investment risk evaluation and its application. J Transp Syst Eng Inf Technol 13(4):94–99

Chapter 135
The Effect of Macroeconomic Factor Fluctuation on Tourism Demand

Junrong Liu

Abstract This paper theoretically and empirically enquires, from the perspective of demand side, the impact of macroeconomic factor fluctuation on Sichuan tourism, such as interest rates, national income and price. The study shows that tourism demand proves elastic to price (CPI), national income (GNI capita) and interest rate, and that price and interest rate fluctuations are negatively correlated with domestic tourism demand, while, with which national income (GNI capita) is positively associated. The study also finds that per capita national income and the local consumer price index enjoy strong predictive power for tourism demand.

Keywords Macroeconomic factor fluctuation · Tourism demand · Effects

135.1 Introduction

Macroeconomic factor fluctuation and regional tourism industry have long been separately and extensively studied by scholars, but these studies rarely cover the long-term relationship between the economic cycle and tourism demand, and the studies on tourism hardly go beyond yearly qualitative evaluation. From the results of the literature review, the researches on the impact of macroeconomic factor fluctuation on tourism are uncommon yet. This article is dedicated to exploring the effect of macroeconomic factor fluctuation on tourism (Sichuan as an example) from demand perspective, which is of great significance for regional tourism policy making and circumventing tourism industrial risk.

In majority of previous literatures, the effect of macroeconomic factor fluctuation on demand in certain sectors is enquired through modeling a series of explanatory variables, and the majority of econometric models introduced the disposable income, interest rate, inflation rate or exchange rates which reflect the macroeconomic factor

J. Liu (✉)
School of Management & Economics, Leshan Normal University,
Leshan 614000, People's Republic of China
e-mail: 1073583914@qq.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_135

fluctuation to interpret industrial demand fluctuation. In some foreign literatures, some scholars also used the similar methods to study the interaction between macroeconomic fluctuations and the tourism industry. Some commonly used explaining variables of the tourism demand can be found in the literatures of Crouch Meta-Analysis [1] (and the works of Witt [8, 9] and Lim). Some researches show that tourism demand is elastic to macroeconomic factor fluctuation indicators. Wong's [10] analyzed the impact of economic fluctuations on the tourism demand and found that the main economic cycle has a significant impact on tourism demand, based on economic variables such as price and disposable income. Gouveia and Rodrigues [2], using non-parameter method by Harding and Pagan's [5] and Hodrick–Prescott filtering method, investigated the synchronization between tourism cycle and economic cycle, and this ground breaking study found that there is a stable lag between them. Guizzardi and Mazzocchi [4] using Harvey STS model (Structural Time Series Approach) studied the economic cycle's influence on the Italy tourism demand, and concluded that there is a lag effect on tourism demand from economic cycle and the impact of economic cycle on the tourism demand is effective.

Qiao and Chen [6] used a vector autoregression model to analyze the response of inbound tourism to fluctuations in major macroeconomic variables by examining the cyclic character of macroeconomic and inbound tourism fluctuations, and found that the tourism economy, as a part of the industrial structure, is inevitably affected by various fluctuations in the macroeconomic environment. The growth of tourism is bound up with the macroeconomic environment, and there were shorter cycles of 2.57 years for inbound tourism with macroeconomic fluctuations. Xia and Hu [11] established a dynamic panel data model and used sys-GMM estimation method to estimate the effect of macroeconomic fluctuations on China's domestic tourism based on the data of 30 provinces in China from 1997 to 2011. With the rate of GDP as the critical volatility factors, inflation, unemployment and rural-urban income gap as the controlling volatility factors, the empirical results lead to following foundlings: the first, the macroeconomic fluctuation on the domestic tourism development has a steady significant positive effect; the second, the inflation rate in the macroeconomic impact of tourism development on the domestic mechanisms plays a dynamic role in promoting; the third, the first lagged period of the unemployment rate showed steady significant negative effect on domestic tourism development, and the unemployment rate in the macroeconomic impact of tourism development on the domestic mechanisms plays a dynamic role in absorption; the forth, the rural-urban income gap showed significant negative effect on domestic tourism development.

We will come to theoretic understanding of the effect of macroeconomic factor fluctuation on tourism demand in the second part. The third part covers the empirical analyses based on Sichuan tourism. The forth part it the conclusions drawn from the paper analyses.

135.2 Theoretic Understanding

Cyclical economic factor fluctuation is an objective reality and affects all socio-economic activities. Tourism economy as an important part of the tertiary industry is also unexceptionally haunted by the impact of macroeconomic volatility. From the demand perspective, domestic tourism is the major part of a country or regional tourism demand, and the main economic factors affecting travel demand are the travel motivation, afford ability, leisure time, macro-political and macro-economic climates and the prices of tourism products, among which domestic per capita income, tax and price are the most direct impacting factors that the macroeconomic fluctuation mainly influence and thereby affects travel demand.

135.2.1 The Influence of Interest Rates on Tourism Demand

Gu [3] explored the impact of interest rates on tourism demand and found that interest rates and travel demand is negatively correlated. Substitution effect and income effect generated by fluctuations of interest rate have a significant impact on resident's tourism demand.

Firstly, changes in interest rates affect people's propensity to save, which help residents to make consumption costs minimized and the inter-temporal consumption utility maximized. In other words, the residents will adjust the proportion of consumption and savings in disposable income according to changes in interest rates. When interest rates increase, current consumption will decrease and savings rise, and future consumption increases. If the distribution of current and future consumption changes, people's travel afford ability and travel demand will be directly affected.

Secondly, fluctuations in interest rates directly affect the residents' return on assets. Although China's capital market is not mature enough, but the fact that the majority of urban residents and the middle class invest in the stocks, funds, bonds and other capital goods is undeniable. In fact, majority of domestic tourists are urban or middle class residents. Therefore fluctuations in interest rates will have a significant impact on their non-wage income. Income effects and substitution effects generated by interest rates should be further strengthened and directly impact people's propensity to consume and thereupon affect the travel demand of residents.

For simplicity, we employ trans-two-period consumption to depict the impact on the interest rate change over tourism consumption. We divided the life-time consumption into the current consumption and future consumption, and citizen's utility function of tourism is $U = U(c_1, c_2)$. It is presumed that citizen has no liquidity constraints, no assets inherited and no heritage for successors. citizen's path of Intertemporal tourism consumption can be depicted as follows:

$$\frac{c_2}{a_2} = y_2 + (1 + r)(y_1 - \frac{c_1}{a_1}),$$

where c_1 and c_2 are the current consumption and the future consumption, y_1, y_2 are the current income and the future income, r is interest rate, and a_1, a_2, $(1 > a_1, a_2 > 0)$ the proportion of the current and the future consumption in gross consumption respectively. Citizen's budget constraint is:

$$\frac{c_1}{a_1} + \frac{c_2}{a_2(1+r)} = y_1 + \frac{y_2}{1+r}.$$

With the fluctuation of interest rate, Citizen has to manage consumption with economic rationality to maximize tourism consumption utility. For current satisfaction, future utility should be discounted, and we notify the future utility discount rate with. Then, citizen tourism consumption maximization can be expressed as follows:

$$\begin{aligned} \max\ U(c_1, c_2) &= \ln\frac{c_1}{c_2} + \frac{1}{(1+\mu)}\ln\frac{c_2}{a_2} \\ s.t.s\frac{c_1}{a_1} + \frac{c_2}{a_2(1+r)} &= y_1 + \frac{y_2}{1+r}. \end{aligned}$$

We construct a Lagrange Function

$$L(c_1, c_2, \lambda) = \ln\frac{c_1}{a_1} + \frac{1}{(1+\mu)}\ln\frac{c_2}{a_2} + \lambda\left[y_1 + \frac{y_2}{1+r} - \frac{c_1}{a_1} - \frac{c_2}{a_2(1+r)}\right].$$

We take the partial derivative of L and note it equals zero

$$\begin{aligned} \frac{\partial L}{\partial c_1} &= \frac{1}{c_1} - \frac{\lambda}{a_1} = 0, \\ \frac{\partial L}{\partial c_2} &= \frac{1}{c_2(1+\mu)} - \frac{\lambda}{\alpha_2(1+r)} = 0, \\ \frac{\partial L}{\partial \lambda} &= \frac{c_1}{\alpha_1} + \frac{c_2}{\alpha_2(1+r)} - \frac{y_2}{1+r} - y_1 = 0. \end{aligned}$$

This eventually leads to

$$\frac{c_2}{c_1} = \frac{\alpha_2(1+r)}{\alpha_1(1+\mu)} \Rightarrow c_2 = \frac{\alpha_2(1+r)}{\alpha_1(1+\mu)}c_1.$$

For utility is positive in usual situation and citizen's marginal utilities in each periods are independent, we assume that utility function is $U(c) = \ln c$.

Taking first order derivative of leads to

$$\frac{U'(c_2)}{U'(c_1)} = \frac{c_1}{c_2} = \frac{\alpha_1(1+r)}{\alpha_2(1+\mu)}. \tag{135.1}$$

We assume the tourism consumption propensities in the two periods are equal, that is $\alpha_1 = \alpha_2$. According to Eq. (135.1), we know that interest rate change exerts significant impact, through and comparison, over tourism consumption in the two periods.

When $r > \mu$, $\frac{U'(c_2)}{U'(c_1)} = \frac{\alpha_1(1+r)}{\alpha_2(1+\mu)} > 1$. This indicates that marginal consumption utility in the second period is less than that in the first period. To maximize consumer intertemporal utility, the consumer consumes more in the first period or cut down consumption in the second period.

When $r < \mu$, $\frac{U'(c_2)}{U'(c_1)} = \frac{\alpha_1(1+r)}{\alpha_2(1+\mu)} < 1$. The consumer consumes less in the first period or increases consumption in the second period.

When $r = \mu$, the market interest rate equals to consumers' subjective preference, and consumer intertemporal utility thus can be maximized.

We assume μ is constant, and divide the consumption time into N periods. Base the logic above, we can conclude that the interest rate change negatively interacts with citizen tourism consumption.

135.2.2 The Influence of National Income on Tourism Demand

We hold that the income and leisure affect each other. When income increases, labor substitutes leisure. But once exceeding the critical point, leisure will replace labor. With the volatility of the economy, wage income and asset income will fluctuate, thereby affecting people's afford ability. Tourism consumption is mainly determined by household disposable income, but household disposable income is hardly independent from the level of income tax. Factually, the family income tax is of stability, and we set it as a constant, and to a large extent, the per capita income can represent the disposable income levels, so that it can partially determine the afford ability of residents. According to some scholars, family income level currently determines the tourism consumption of a Chinese family, and income fluctuation will have the increasing marginal effects on travel demand.

We notify y_t as citizen average income, τ_t as income tax rate at time, y_t as disposable earnings. y_t can be depicted as follows:

$$y_t = \beta_t Y_t(1 - \tau_t), 1 > \beta > 0, 1 > \tau_t > 0.$$

Based on Keynes's Absolute Income Hypothesis, citizen's tourism consumption interacts with income based on the following pattern:

$$\begin{aligned} C_t &= \pi + \beta_t y_t, \\ C_t &= \pi + \beta_t Y_t(1 - \tau_t), \end{aligned} \tag{135.2}$$

where C_t is average tourism consumption, and β_t is the parameters to be estimated. β_t is actually the marginal tourism consumption propensity.

The partial derivative of Eq. (135.2) is

$$\frac{\partial C_t}{\partial Y_t} = \beta_t(1-\tau_t).$$

For $1 > \beta > 0$, $1 > \tau > 0$,

$$\frac{\partial C_t}{\partial Y_t} = \beta(1-\tau_t) > 0. \tag{135.3}$$

Equation (135.3) indicates that income positively interrelates with tourism consumption.

Additionally, income fluctuation influences working and leisure time allocation thus exert impact on tourism consumption. Higher income leads to less leisure time, but when income is higher than critical point, tourism consumption is bound to rise up.

135.2.3 The Influence of Price on Tourism Demand

The impact of price on demand is self-evident, and nearly all the economists to reach a consensus that price negatively correlates with consumer demand Comparing with general merchandise, tourism products have uniqueness, monopoly or non-essential features, but in the situation of normal prices or national income, tourism goods are normal goods. Given other cases unchanged, the tourism demand of residents depends on the prices of tourism products.

We notify the average citizen working time L, wage and gross time for work and leisure T (T is constant as presumed). I_0 is the initial wealth, $\varphi(\omega L + L_0)$ is the utility brought by the initial wealth, and $\psi(T-L)$ is the utility brought by leisure, wherein p is the domestic price for goods and services and ϕ, must meet the following conditions:

$$\phi(x) > 0, \phi'(x) > 0, \phi''(x) < 0; \sigma = -x\frac{\phi''(x)}{\phi'(x)}; \psi'(x) > 0, \psi''(x) < 0.$$

And the gross utility is $U(L) = \phi((wL + I_0)p) + \psi(T-L)$.

We presume $T - L = \rho$, then the gross utility is

$$U(T-\rho) = \phi\left((w(T-\rho) + I_0)p\right) + \psi(\rho).$$

When $T - L = \rho_0$, the gross utility is maximized, that is

$$\frac{dU}{d\rho}(\rho_0) = 0,$$

then

$$\phi'\left((w(T-\rho_0)+I_0)p\right)\times(-wp)+\psi'(\rho_0)=0.$$

This means ρ_0 is a function of I_0, p, that is

$$\rho_0=\rho_0(w, I_0, p).$$

For explore the relationship between ρ_0 and w, p we get

$$\begin{aligned}&\phi''\left((w(T-\rho_0)+I_0)p\right)\times(-wp)\left((w(T-\rho_0)+I_0)+w(-\frac{\partial\rho_0}{\partial p})p\right)\\&-w\phi'\left((w(T-\rho_0)+I_0)p\right)+\psi''(\rho_0)\frac{\partial\rho_0}{\partial p}=0.\end{aligned}\tag{135.4}$$

From Eq. (135.4). we get

$$\frac{\partial\rho_0}{\partial p}=\frac{\phi''\left((w(T-\rho_0)+I_0)p\right)(w(T-\rho_0)+I_0)wp+w\phi'\left((w(T-\rho_0)+I_0)p\right)}{\phi''(w(T-\rho_0)+I_0)(wp)^2+\psi''(\rho_0)},\tag{135.5}$$

which can be rewritten as

$$\begin{aligned}\frac{\partial\rho_0}{\partial p}&=\frac{w\phi'\left((w(T-\rho_0)+I_0)p\right)}{\phi''(w(T-\rho_0)+I_0)(wp)^2+\psi''(\rho_0)}\\&\left\{1+\left((w(T-\rho_0)+I_0)p\right)\frac{(wp)\phi''\left((w(T-\rho_0)+I_0)p\right)}{w\phi'\left((w(T-\rho_0)+I_0)p\right)}\right\}.\end{aligned}$$

Based on the known conditions, we get

$$\frac{\partial\rho_0}{\partial p}=\frac{w\phi'\left((w(T-\rho_0)+I_0)p\right)}{\phi''(w(T-\rho_0)+I_0)(wp)^2+\psi''(\rho_0)}\left\{1-p\sigma\right\}.$$

Because $\phi'(x)>0, \phi''(x)<0, \Psi''(x)<0$

$$\frac{w\phi'\left((w(T-\rho_0)+I_0)p\right)}{\phi''(w(T-\rho_0)+I_0)(wp)^2+\psi''(\rho_0)}<0.$$

When $1-p\sigma>0\Rightarrow\sigma<\frac{1}{p}, \frac{\partial\rho_0}{\partial p}<0$. This indicates price negatively, that is the lower the price is, the more leisure time and vice versa.

When $1-p\sigma>0\Rightarrow\sigma<\frac{1}{p}, \frac{\partial\rho_0}{\partial p}>0$. This indicates price positively, that is the higher the price is, the more leisure time and vice versa.

When $1-p\sigma>0\Rightarrow\sigma<\frac{1}{p}, \frac{\partial\rho_0}{\partial p}=0$. This indicates $p=p^*$, and p^* is the critical value between p^n and p^{an}.

135.3 Empirical Analyses

135.3.1 Modeling

Based theoretical analyses, we build following econometric model:

$$\ln Y_t = a_0 + a_1 \ln P_t + a_2 \ln I_t + a_3 \ln R_t + \mu_t, \tag{135.6}$$

where Y_t denotes the Sichuan domestic tourism income at time t, and P_t is the price of the domestic tourism products at, and I_t is national per capita income at t; R_t denotes the real interest rate at t, and μ_t is the random error, and a_0, a_1, a_2, a_3 are parameters, and a_1, a_2 and a_3 are price elasticity, income elasticity and interest rate elasticity of Y_t.

135.3.2 Data Description

We have chosen Sichuan tourism income Y_t and domestic tourist arrivals (annual average) to represent changes in the domestic tourism demand in Sichuan and China's per capita national income and real interest rates in China to reflect domestic economic fluctuations. Price fluctuation is indicated by the national consumer price index or the Sichuan Consumer Price Index. We select sample data for 1991 to 2010. Consumer price index and interest rates are collected from the national statistical yearbooks, and China's per capita national income comes from the official website of the World Bank.

In further indicator selection, we have the considerations as follows:

First, Sichuan Consumer Price Index has a high synchronization with the National consumer price index. For both reflect macroeconomic fluctuations and Sichuan tourism product prices, so I chose the former.

Second, we also found a high level of synchronization between Sichuan yearly tourism income and domestic yearly tourist arrivals, between which the correlation coefficient amounts over 0.9. For the unity of the data nature, we choose Sichuan domestic tourism income as the empirical sequence and discard the population of domestic yearly tourist arrivals.

Third, this paper employs, mainly based on rational consumer presumption, the real interest rate as one of the explanatory variables, which is, because rational consumers make decisions based on real interest rates rather than the nominal interest rate in their inter-temporal consumption [7].

Therefore, based on the theme of this paper, we set Sichuan domestic tourism income Y_t as the dependent variable, and per capita income in China ($ID = I_t$), China's real interest rate ($RD = R_t$) and Sichuan consumer price index ($\text{CPID} = P_t$) as explanatory variables. All the empirical tests are conducted in Eviews5.0 environment.

135.3.3 Analyses Results

(1) Regression Analysis

For a long-term equilibrium analysis on effects of macroeconomic volatility over Sichuan domestic tourism demand, We employed the least squares method to make a regression test with Sichuan tourism demand $\ln Y_t$, per capita income $\ln I_t$, the real interest rate $\ln R_t$ and Sichuan Consumer price index $\ln P_t$, and results are as follows:

$$\ln Y_t = -\,1.512220666 \ln P_t + 1.126388816 \ln I_t - 1.923482888 \ln R_t + 7.175236834.$$
$$(-1.849962)(23.49877)(-2.796301)(1.873789)$$

$$\text{R-squared} = 0.972470, \quad \text{Adjusted R-squared} = 0.967309, \quad \text{D-W stat} = 2.231994,$$

$$\text{F-statistic} = 188.3979, \quad \text{Prob(F-statistic)} = 0.00000.$$

It can be seen from the above equation that the estimated regression coefficients a_2, a_3 are by 5 % level T-test of significance, a_1 by 10 % level. That is, all explanatory variables meet the test of significance. While, the equation F-test is also very significant, indicating that the model represent a strong linearity. Adjusted coefficient of determination (R^2), 0.967309, implies the high level of model goodness of fit, and the D-W-stat value (2.231994) on the 1 % significance level admits the non-existence of first-order autocorrelation assumptions.

The regression coefficients inform that Sichuan Consumer Price Index (P_t), China's real interest rate R_t and travel demand Y_t are negatively correlated. When Sichuan Consumer Price Index increases by 1 %, Sichuan tourism income decreases by more than 1.5 %. And when the domestic real interest rate increases by 1 %, the Sichuan tourism demand drops by 1.92 %. While, the per capita income and Sichuan tourism demand are positively correlated. With per capita income increase by 1 %, Sichuan tourism demand increases by 1.12 %. The test results show that Sichuan tourism demand are elastic to these macroeconomic indicators a Summarily speaking, the of impact macro-economic fluctuation on Sichuan tourism is remarkable.

(2) Impulse Response Analysis

To further analyze the impact of the macroeconomic fluctuation on tourism in Sichuan, we conduct the impulse response test. The test results (Fig. 135.1) shows that the impulse response of Sichuan domestic tourism to Sichuan Consumer Price Index (CPID) reaches the peaks in period one, period three, period five and period seven and stabilize in the lag of 8 years, and the long-term impact proves negative. The response of Sichuan domestic tourism demand to national income per capita (*ID*) remains moderate overall, and relatively more significant in period two, and the response of Sichuan tourism demand to national per capita income stays positive after period four and long-term. Real interest rate (*RD*) affects Sichuan tourism demand positively in the first two periods. And the impulse response reaches the positive maximum and after the third period, the impulse response turn negative and reaches the highest negative value in period four, and then tends to be stable after

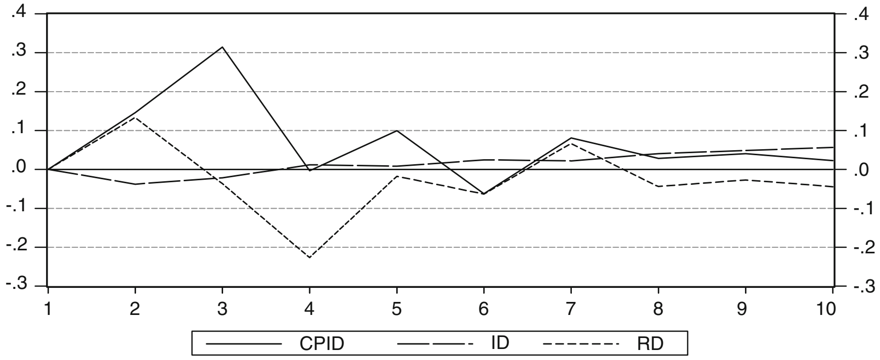


Fig. 135.1 Impulse response analysis

Table 135.1 Variance decomposition(%)

Period	SC.TI	*ID*	Int.R	CPI
1	100	0	0	0
2	47.45186	27.71605	1.865647	22.96644
3	20.82278	67.44508	1.066823	10.66532
4	16.54933	52.09786	0.883452	30.46936
5	15.91501	53.93868	0.872916	29.27339
6	17.73483	52.15454	1.056506	29.05412
7	17.18329	52.2407	1.183047	29.39296
8	18.48157	50.72023	1.737984	29.06022
9	18.98392	49.95099	2.513391	28.5517
10	20.27002	48.1547	3.484461	28.09082

period eight. Generally speaking, real interest rate affects Sichuan domestic tourism demand negatively.

(3) Variance Decomposition

In order to better understand the variance contribution of the macro explanatory variables to Sichuan domestic tourism demand, we further conduct variance decomposition test on Sichuan domestic tourism demand. Table 135.1 shows that, in the forecast variance of Sichuan tourism demand, the contribution of per capita income, interest rates and CPI turn to be stabilized in period four, period one and period three respectively. Therefore, we believe that the per capita income affects Sichuan domestic tourism demand with a time lag of four periods, the interest rate with a time lag of one period and consumer price index within a time lag of three periods. It can be observed from Table 135.1 that in period 10, the knock-on effects of national per capita income, real interest rates and Sichuan consumer price index on Sichuan domestic tourism demand are 48.15, 1.48 and 28.09 % respectively.

135.4 Conclusion

In this paper, we select China's national per capita income, Sichuan consumer price index and real interest rates, which largely represent the macroeconomic situation and business cyclical fluctuations. The study herein found that the changes in these indicators render significant impact on the domestic tourism demand in Sichuan as a case. Particularly speaking, the fluctuations in national per capita income and real interest rate are negatively correlated with Sichuan domestic tourism demand, while national per capita income is positively correlated with it.

Since the macroeconomic indicators that we use in this paper have different time lag to and impaction Sichuan tourism, Sichuan tourism authorities should take such differences into their policy making to weaken the possible "overkill" impact. From the results of the forecast variance decomposition, the per capita income is the best indicator as weathercock and intermediate target for Sichuan domestic tourism demand, which is also consistent with the theoretical analysis in this paper. And according to the study, the consumer price index also deserves authority's attention for its importance in Sichuan tourism regulation and promotion. The regression analysis result shows the interest rate elasticity of Sichuan domestic tourism demand is considerable comparatively, so the interest rate is well of availability as a control tool. However, for the local government, Sichuan consumer price index as a regulatory agent proves even more maneuverable and efficient than national per capita income and interest rates.

Acknowledgments The paper funded by the National Social Science Fund Project (14XJL007).

References

1. Crouch GI (1996) Demand elasticities in international marketing: a meta-analytical application to tourism. J Bus Res 36(2):117–136
2. Gouveia PM, Rodrigues PM (2005) Dating and synchronizing tourism growth cycles. Tour Econ 11(4):501–515
3. Gu Z (1995) The relationship between interest rate and tourism activities. Int J Hosp Manage 14(3):239–243
4. Guizzardi A, Mazzocchi M (2010) Tourism demand for italy and the business cycle. Tour Manage 31(3):367–377
5. Harding D, Pagan A (2003) A comparison of two business cycle dating methods. J Econ Dyn Control 27(9):1681–1690
6. Qiao N, Chen J (2013) Impact of macroeconomic fluctuations on China's inbound tourism. Tour Trib 2:0–10
7. Wang L, Tan D (2005) Eba model for relationship between economic growth and marketization level in China. J Econ Dyn Control 40(6):822–825
8. Witt SF, Witt CA (1995) Forecasting tourism demand: a review of empirical research. Int J Forecast 11(3):447–475
9. Witt SF, Song H, Louvieris P (2003) Statistical testing in forecasting model selection. J Travel Res 42(2):151–158

10. Wong KK (1997) The relevance of business cycles in forecasting international tourist arrivals. Tour Manage 18(8):581–586
11. Xia Z, Yue H (2014) The dynamic effect of macroeconomic fluctuations on China's domestic tourism: evidence from dynamic panel data model with GMN estimation. Tour Trib 2:16–23

Chapter 136
A Dynamic Evaluation of the Comprehensive Carrying Capacity of Chengdu Urban

Yunqiang Liu and Fang Wang

Abstract Cities are complex artificial systems with an effect of strong leading role and radiation. This article reflects the four areas selected departure city group resources, environment, economic and social indicators from 24 representatives divided into pressure force and support force. Firstly, using entropy method gives 24 index weights. Then, using TOPSIS method to evaluate Chengdu city group's comprehensive carrying capacity and various subsystems' carrying capacity in 2013. During the evaluation process, using the System Cluster method to differentiate the cities. Chengdu city group is separated into three levels. And then dynamically evaluating Chengdu city group's each subsystem carrying capacity and comprehensive carrying capacity from 2009 to 2013 using Coefficient of variation. Observing the changes of situation and trends of each subsystem carrying capacity and comprehensive carrying capacity. The results show that Chengdu city group space has a significant degree of difference. Chengdu is the absolute leader and the Ya'an City is the disadvantaged. The degree of resource dependence is high. Social subsystem carrying capacity is lacking and weak. Cities' comprehensive carrying capacity fell and then has stabilized trend. Lastly, in this paper, based on analysis results, referring to the features of Chengdu city group and coming up with the suggestions and development strategies of improving the comprehensive carrying capacity.

Keywords City comprehensive · Carrying capacity · Entropy method · TOPSIS method · Spatial differentiation

136.1 Introduction

Under the background of economic globalization, international competition is becoming increasingly fierce. In this circumstance, a country's comprehensive competitiveness depends a lot on whether it possesses urban agglomeration and urban

Y. Liu · F. Wang (✉)
School of Management, Sichuan Agricultural University, Chengdu 611130, People's Republic of China
e-mail: wangfangscnd@sicau.edu.cn

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_136

zone with strong economies. Chinese urbanization, of which metropolis circle, urban agglomeration, city zone and central cities are principal forms, is in a period of rapid development. Urban agglomeration, developed from big cities, is a reflection of the development of regional space to a certain extent. Urban agglomeration helps to bring agglomeration economics effect. The 13th Five-Year Plan determines to create a "4 + 3" pattern based on the primary four regional plates and finally forms a regional development layout connecting the square urban agglomeration and city zone. Urban agglomeration area has become the core area in the economic development pattern with the most vitality and potential as well as the core fulcrum of productivity layout of China. As it has the function of converging and spreading all sorts of production factors, the study of urban agglomeration is of great significance.

Carrying capacity, initially mentioned in ecology, refers to the maximum number of an individual species that can be maintained in a certain circumstance within a certain area. In the field of human ecology, Park and Burgess applied the concept of carrying capacity in relative studies [5]. They believed that food resources could determine the population capacity in one area, which promoted the research of land carrying capacity. In his "Ecology Principle", Odum combines the concept of carrying capacity with theoretical K-value in logistic curve so that carrying capacity can be expressed in the form of mathematics [4, 6]. In 1960 s and 1970s, with the rapid development of industrialization and urbanization as well as the fast growth of global population, the research focus of carrying capacity has transferred to studying human economic and social development under the restriction of resource environment; at the same time, concepts of resource carrying capacity (land, water, minerals and so on), environmental carrying capacity and ecological carrying capacity gradually emerged. For instance, traffic carrying capacity mainly refers to the capacity of vehicles in cities and traffic environmental carrying capacity [1]. In early 1980s, UNSESCO put forward "resource carrying capacity". It refers to the population size that a country or an area can continuously support in a predicted period by making use of local resources, natural resources and technology, ensuring the material living standard complying with the social and cultural norms [7]. In the past 20 years, the concept of carrying capacity was widely applied and studied in the fields of the management of population and natural resources as well as environmental planning and management. Plenty of definitions and quantitative models about carrying capacity were proposed. Hardin and Daily further introduced the notions of biological physical bearing capacity, cultural carrying capacity and social carrying capacity, etc., and developed from single factor to comprehensive carrying capacity restricted by multiple elements [2, 3]. In a whole, urban comprehensive carrying capacity is an organic combination of resource carrying capacity, environmental carrying capacity, economic carrying capacity and social carrying capacity.

By studying the comprehensive carrying capacity of urban agglomeration, the author aims to reveal the carrying mechanism of urban agglomeration and enhance the validity and pertinence of relative policies applied in urban agglomeration. Selecting Chengdu urban agglomeration in Chengdu-Chongqing Economic Zone and 24 representative indexes in four aspects of resources, environment, economics and society, this paper makes an integrated evaluation of the comprehensive carrying capacity of all the subsystems in Chengdu urban agglomeration in 2013 by using the methods of entropy and TOPSIS. Besides, the author makes a spatial differentiation research of urban agglomeration by using systematical clustering method, diving Chengdu urban agglomeration into three levels. Then the paper carries a dynamic evaluation of the comprehensive carrying capacity of all subsystems in Chengdu urban agglomeration from 2009 to 2013 and analyzes the changing situation and changing trend. Finally, based on the development advantages and disadvantages of Chengdu urban agglomeration, the author puts forwards some tentative suggestions in order to promote the new urbanization development in the background of "The Belt and Road".

136.2 An Overview of the Research Area

The research subject of this paper is Chengdu urban agglomeration, covering the cities of Chengdu, Mianyang, Deyang, Suining, Meishan, Yaan, Ziyang as well as the central area, Shanwan area, Wutongqiao area, Jinkouhe area, Jiajiang county and Emeishan of Leshan city. The administrative area is about 78 thousand square kilometres, which occupies 37.9 % of Chengdu-Chongqing Economic Zone. The permanent population is 35.86 million by the end of 2013, which is 38.6 % of Chengdu-Chongqing Economic Zone. The regional GDP is 1591.1 billion yuan, 44.7 % of Cheng-Yu Economic Zone. The eight cities will share the unified and fixed telephone area code, meanwhile the qualified areas will open intercity buses. Finally the whole area will realize integrative development.

In June, 2014, the general office of Sichuan provincial government issued a document named "Development Planning of Chengdu Urban Agglomeration in Chengdu-Chongqing Economic Zone (2014–2020)". In the context of Western Development and "The Belt and Road" development opportunity, the development and status of Chengdu urban agglomeration, as the core of western area, will be further shown.

136.3 Model Building

136.3.1 Index System Establishment and Data Sources

Referring to the existing evaluation index system of research results and considering the factors of resource supply, urban traffic pressure, urban environment, medical conditions and educational situation, at the same time following the basic principles of constructing an index system, namely systematicness, typicalness, dynamism, scientificalness, comparability and integrity, this paper decomposes the evaluation system of urban comprehensive carrying capacity into four subsystems, which are resource subsystem, environment subsystem, economy subsystem and society subsystem; meanwhile, the paper selects 24 representative indexes. Based on all the above factors, the evaluation system of Chengdu urban comprehensive carrying capacity is established (Table 136.1). NOTE: Research data mainly comes from "China City Statistical Yearbook (2009–2013) and "Leshan Statistical Yearbook (2009–2014)".

Urban agglomeration, as a complex system, is an aggregation of relatively independent urban communities. The indexes selected in constructing an evaluation system of comprehensive carrying capacity reflect the holding power and pressure of a city. Meanwhile, the holding power index and pressure index relating to four aspects, namely resource, environment, economics and society reflect the comprehensive carrying capacity of a city. The built-up area, total volume of water supply and gas supply show the situation of resource utilization, while construction land per capita, residential water consumption and total social electricity consumption show the resources demand. Industrial sulphur dioxide, volume of industrial soot emission and volume of industrial wastewater discharge reflect the pollution situation of urban environment, however comprehensive utilization of waste, sewage treatment rate and green space of built-up area is a reflection of a city's environmental treatment situation. Per capita GDP and GDP growth rate represent a city's development situation; passenger capacity reflects a city's traffic situation; population and unemployment reflect a city's demographic situation; the number of post offices at the end of a year represents a city's postal service level; average ownership of hospital beds per 10000 people and technology and education expenditure reflect a city's medical service condition and educational condition. All the 24 indexes chosen is a comprehensive reflection of the resources, environmental, economic and social conditions.

136.3.2 Standardized Treatment of Evaluation Indexes

All the 24 selected indexes consist of total quantity index and intensity index, each with different units and dimension, therefore standardized treatment to these indexes is necessary firstly. Suppose the scheme set of the comprehensive carrying capacity of Chengdu urban agglomeration be $A = \{A_1, A_2, A_3, \ldots, A_n\}$, the index set be $D = \{D_1, D_2, D_3, \ldots, D_n\}$, the holding power index in the evaluation system is benefit index and the pressure index is cost index, then standardized treatment is analyzed as follows:

Benefit index:

$$z_{ij} = (x_{ij} - x_{j\,\min})/(x_{j\,\max} - x_{j\,\min}), (i = 1, 2, 3 \cdots, n; j = 1, 2, 3 \cdots, m). \tag{136.1}$$

Cost index:

$$z_{ij} = (x_{j\,\max} - x_{ij})/(x_{j\,\max} - x_{j\,\min}), (i = 1, 2, 3 \cdots, n; j = 1, 2, 3 \cdots, m). \tag{136.2}$$

Table 136.1 The evaluation index system and degree of importance of the comprehensive carrying capacity in Chengdu urban agglomeration (A)

Resource subsystem (B1)	Pressure index (C1)	Construction land per capita (10000 persons/square kilometers) (D1)
		Residential water consumption (10000 tons) (D2)
		Total social electricity consumption (10000 kwh) (D3)
	Holding power index (C2)	Built-up area (square kilometers) (D4)
		Total volume of water supply (10000 tons) (D5)
		Total volume of gas (artificial gas,natural gas) supply(10000/cubic metres) (D6)
Environment subsystem (B2)	Pressure index (C2)	Volume of industrial sulphur dioxide emission (ton) (D7)
		Volume of industrial soot emission (ton) (D8)
		Volume of industrial waste water discharge (10000 tons) (D9)
	Holding power index (C4)	Comprehensive utilization rate of industrial solid wastes (%) (D10)
		Urban sewage treatment rate (%) (D11)
		Green coverage rate of built-up areas (%) (D12)
Economic subsystem (B3)	Pressure index (C5)	Number of industrial enterprises (piece) (D13)
		Average GDP (yuan) (D14)
		GDP growth rate (%) (D15)
	Holding power index (C6)	Gross industrial output value(current price10000 yuan) (D16)
		Proportion of secondary industry and third industry (%) (D17)
Social subsystem (B4)	Pressure index (C7)	Annual average population (10000 people) (D18)
		Passenger capacity(10000 people) (D19)
		Number of registered unemployed persons in cities and towns at the end of a year (person) (the whole city) (D20)
	Holding power index (C8)	Average wage of staff (yuan) (D21)
		Average ownership of hospital beds (piece/10000 people) (D22)
		The number of post offices at the end of a year (unit) (D23)
		Technology and education expenditure (10000 yuan) (D24)

In the formula, x_{ij} refers to the number of indexes i of the j city, $x_{j\,\min}$ and $x_{j\,\max}$ mean the minimum and maximum of index D. The decision matrix after standardized treatment is $Z = (z_{ij})_{n\times m}$, from this decision matrix, it is known that the bigger z_{ij} is, the better.

136.3.3 The Construction Process of Evaluation Model

(1) The Selection of Ways of Empowerment

There are many ways of deciding the indexes concerning degree of importance, of which subjective weighting method and objective weighting method are the most common. The former includes AHP method, statistical averaging method, Delphi method and so on; while the latter consists of BP nerve net algorithm, variation coefficient method, entropy method and so on. Objective weighting method, removing subjectivity, has a stronger persuasiveness. Entropy method is used in this paper, with the principle as follows:

Suppose the multi-attribute decision matrix be:

$$M = \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & x_{mn} \end{bmatrix}. \tag{136.3}$$

$D_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}$ represents the contribution degree of A_i of the j city.

H_j represents entropy of information of "i index".

$$H_j = -K \sum_{i=1}^{n} D_{ij} \ln(D_{ij}). \tag{136.4}$$

In which the constant $K = 1/\ln(n)$ (If $D_{ij} = 0$, $D_{ij} \ln f_{ij} = 0$).

After determining the entropy value, we can define the entropy w_{ij} of "i index" of "m city":

$$w_{ij} = \frac{1 - H_i}{n - \sum_{i=1}^{n} H_i}, \quad w_{ij} \in [0, 1]. \tag{136.5}$$

and normalized weighting entropy matrix be :

$$W = \begin{bmatrix} W_1 & 0 & \cdots & 0 \\ 0 & W_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & W_n \end{bmatrix}. \tag{136.6}$$

(2) Selection of Evaluation Model

On the basis of determining weight by using entropy method, we apply TPOSIS model to measure the comprehensive carrying capacity of Chengdu urban agglomeration. The procedures are as follows:

Defining the optimal solution and the worst solution of the j city:

$$W^+ = \left\{ (\max_{1 \le i \le n} w_{ij}, \quad i \in I_1), (\min_{1 \le i \le n} w_{ij}, \quad i \in I_2) \; j = 1, 2, \ldots, m \right\}, \tag{136.7}$$

$$W^- = \left\{ (\min_{1 \le i \le n} w_{ij}, \quad i \in I_1), (\max_{1 \le i \le n} w_{ij}, \quad i \in I_2) j = 1, 2, \ldots, m \right\}. \tag{136.8}$$

I_1 be the index set of holding power, I_2 be the index set of pressure; W^+ be the optimal solution and the worst solution of holding power index, W^- be the optimal solution and the worst solution of pressure index.

To calculate the distance between the evaluation object and the optimal solution (also the worst solution):

$$d_j{}^+ = \sqrt{\sum_{i=1}^{n} (w_{ij} - w_i{}^+)^2} \;\; (j = 1, 2, \ldots, m), \tag{136.9}$$

$$d_j{}^- = \sqrt{\sum_{i=1}^{n} (w_{ij} - w_i{}^-)^2} \;\; (j = 1, 2, \ldots, m). \tag{136.10}$$

To determine the relative proximity between the "j city" and the optimal solution:

$$U_j = \frac{d_j{}^-}{d_j{}^+ + d_j{}^-}, \quad j = 1, 2, \ldots, m; \quad U_j \in [0, 1]. \tag{136.11}$$

The bigger the value of U_j is, the closer it is to the optimal solution.

136.4 Empirical Research

136.4.1 The Research on the Carrying Capacity of the Subsystems in Chengdu Urban Agglomeration

In Diagram 1, the evaluation index system of the comprehensive carrying capacity of Chengdu urban agglomeration consists of four subsystems, taking resource subsystem as an example, the evaluation procedures are as follows: To substitute the original data of holding capacity index into Eqs. (136.1) and (136.2), the standardized matrix

(1×6) (from D_1 to D_6) is obtained, namely the indexes representing the resource subsystem:

$$z_{ij(1\times6)} = \begin{Bmatrix} 0.0000 & 0.1223 & \cdots & 1.0000 \\ 0.7631 & 0.6265 & \cdots & 0.0714 \\ \vdots & \vdots & \ddots & \vdots \\ 0.6712 & 0.7345 & \cdots & 0.000 \end{Bmatrix}. \tag{136.12}$$

By combining Eqs. (136.4) and (136.5), we can calculate and construct the weighted normalized matrix:

$$W_{(1\times6)} = \begin{Bmatrix} 0.0186 & 0 & \cdots & 0 \\ 0 & 0.0244 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 0.0792 \end{Bmatrix}. \tag{136.13}$$

According to Eq. (136.6), by Eqs. (136.12) and (136.13) we can obtain the weighted entropy matrix of the resource subsystem:

$$W'_{(1\times6)} = \begin{Bmatrix} 0.0000 & 0.0030 & \cdots & 0.0792 \\ 0.0142 & 0.0153 & \cdots & 0.0056 \\ \vdots & \vdots & \ddots & \vdots \\ 0.0125 & 0.0179 & \cdots & 0.0000 \end{Bmatrix}. \tag{136.14}$$

Through Eqs. (136.7) and (136.8), the optimal solution and the worst solution of the resource subsystem of Chengdu urban agglomeration is defined as shown in Table 136.2:

Through Eqs. (136.9), (136.10) and (136.11), we can determine the positive and negative distance value of resource subsystem as well as the relative proximity and ranking. The ranking is based on the relative proximity; the greater the relative proximity, the higher the ranking is (Table 136.3).

Table 136.2 The optimal solution and the worst solution of the resource subsystem

The optimal solution	The worst solution
0	0.0274927
0	0.0148601
0	0.0150381
0.095819	0
0.1560164	0
0.1080516	0

Table 136.3 The evaluation results of urban resource subsystem of Chengdu urban agglomeration in 2013

City	Positive distance	Negative distance	Relative proximity	Ranking
Chengdu	0	0.2154074	1	1
Deyang	0.1968337	0.0245387	0.1108482	3
Mianyang	0.1856436	0.0397865	0.1764915	2
Ziyang	0.2137488	0.0040542	0.0186142	7
Meishan	0.2119112	0.009456	0.0427162	6
Partial area of Leshan	0.1962412	0.0221998	0.1016284	4
Suining	0.2078018	0.01179	0.0536905	5
Yaan	0.2149644	0.0022546	0.0103795	8

Likewise, the relative proximity of environment subsystem,economic subsystem as well as social subsystem can be obtained. The evaluation results are shown in Table 136.4.

136.4.2 The Evaluation of the Comprehensive Carrying Capacity of Chengdu Urban Agglomeration

(1) The Evaluation Results of the Comprehensive Carrying Capacity of Chengdu Urban Agglomeration

In this part, evaluation of the carrying capacity of all subsystems of Chengdu urban agglomeration have been finished. However, this thesis focuses on the research of the comprehensive carrying capacity of Chengdu urban agglomeration. Referring to the evaluation process of every subsystem, by Eqs. (136.7), (136.8), (136.9) and (136.10), we can calculate the optimal solution and the worst solution of all 24 indexes. Meanwhile, the relative proximity is also obtained, which can reflect the ranking of urban comprehensive carrying capacity. The evaluation results of the comprehensive carrying capacity of Chengdu urban agglomeration in 2013 are shown in Table 136.5.

(2) Hierarchical Cluster Analysis of the Comprehensive Carrying Capacity of Chengdu Urban Agglomeration

By making use of the classification features to further evaluate the comprehensive carrying capacity of Chengdu urban agglomeration, the thesis makes a hierarchical cluster analysis thus form a cluster tress hierarchical figure. The figure is generated through the method of average linkage between groups.

Chengdu urban agglomeration can be classified into three categories according to the comprehensive carrying capacity; with the first category being Chengdu city,

Table 136.4 The evaluation results of every subsystem of Chengdu urban agglomeration in 2013

City\Index	Resource subsystem		Environment subsystem		Economic subsystem		Social subsystem	
	Relative proximity	Ranking	Relative proximity	Ranking	Relative proximity	Ranking	Relative	Ranking
Chengdu	1	1	0.9058	1	1	1	0.4127	2
Deyang	0.1108	3	0.5544	3	0.3416	2	0.2649	4
Mianyang	0.1765	2	0.5532	4	0.2389	6	0.3407	3
Ziyang	0.0186	7	0.373	7	0.326	4	0.6919	1
Meishan	0.0427	6	0.444	5	0.3079	5	0.1871	5
Partial area of Leshan	0.1016	4	0.5589	2	0.3369	3	0.0468	8
Suining	0.0537	5	0.3715	8	0.1878	7	0.1338	7
Yaan	0.0104	8	0.4218	6	0.1113	8	0.1385	6

Table 136.5 The evaluation results of the comprehensive carrying capacity of Chengdu urban agglomeration in 2013

City	Relative proximity	Ranking
Chengdu	0.6942098	1
Deyang	0.2164473	4
Mianyang	0.2555159	3
Ziyang	0.3469218	2
Meishan	0.167172	6
Partial Area of Leshan	0.1849393	5
Suining	0.1257298	7
Yaan	0.1124909	8

the second including Deyang city, partial area of Leshan city, Mianyang city and Meishan city, the third one consisting of Suining city, Ziyang city and Yaan city.

136.4.3 A Dynamic Evaluation Research of the Comprehensive Carrying Capacity of Chengdu Urban Agglomeration

In Sect. 136.4.2 and Sect. 136.4.2, the thesis makes separate researches both on the carrying capacity of all subsystems and the comprehensive carrying capacity in Chengdu urban agglomeration. By processing the original data from 2009 to 2013 according to the above formulas, we can get to know the changing situation of the ranking of Chengdu urban agglomeration.

The degree of variation of two or more indexes can be compared by using coefficient of variation. Therefore the method of coefficient of variation is used to make a research on situation of comprehensive carrying capacity of Chengdu urban agglomeration. The formulas are as follows:

$$C.V = \frac{S}{\overline{x}} \times 100\,\%. \tag{136.15}$$

136.4.4 Result Analysis

(1) Analysis of the Carrying Capacity of All Subsystems in Chengdu Urban Agglomeration

① On the whole, Chengdu city keeps the front position in the subsystems of resource, environment and economics, while ranks second in social subsystem.

Among them, the relative proximity of resource subsystem and economic subsystem of Chengdu city tends to 1.00, which is much higher than other cities in Chengdu urban agglomeration.

② Deyang city and Mianyang city belong to the second category, in which the relative proximity of resource subsystem being around 0.1, environment subsystem being around 0.5 and economic subsystem being around 0.2–0.3. Deyang city occupies certain advantage, whose relative proximity of social subsystem being 0.26–0.34. Comparing the relative proximity of four subsystems, Deyang city is better than other cities expect for Chengdu City.

③ Ya'an city performs poorly in the carrying capacity of resource subsystem, social subsystem and economic subsystem. Among which the relative proximity of resource subsystem is only 0.0104 (2013), much lower than other cities in Chengdu urban agglomeration. However, as a well-known tourist city, Yaan city performs well in environment subsystem.

④ The carrying capacity of resource subsystem has the greatest impact on the comprehensive carrying capacity of Chengdu urban agglomeration. According to Matrix 13, the weight of resource subsystem (B1) in 2013 was 0.4172, being the highest among the four subsystems; among which the weight of total water supply (D5) was 0.1560, being the highest among the 24 indexes.

⑤ The carrying capacity of social subsystem acts as the obstacle of the comprehensive carrying capacity of Chengdu urban agglomeration. Analyzing the relative proximity and ranking of all subsystems, we can get the result that the highest relative proximity of social subsystem is only 0.6919, which is much lower than the relative proximity of other subsystems; meanwhile the weight of social subsystem is 0.2843.

(2) The Analysis of the Comprehensive Carrying Capacity of Chengdu Urban Agglomeration

① The relative proximity of the comprehensive carrying capacity of Chengdu city is high, ranking the first position. The ranking accords with the relative proximity of the comprehensive carrying capacity in resource subsystem, environment subsystem, economic subsystem and social subsystem. Chengdu city is an important central city of western China and is also a famous historical and cultural city. As a technology, trade and financial center as well as the transportation and communication hub of southwest China authorized by State Council, Chengdu city plays the core role in the urban agglomeration, promoting the development of other cities.

② The comprehensive carrying capacity of Mianyang city and Deyang city keeps the front position, while there is still a wide gap comparing to Chengdu city. Since the founding of the people's Republic of China, the two cities have shared the relationship of brotherhood. Concentrating on military high-tech industry and heavy industry in the past, now both of them have transformed to be developed areas of private economy, with the comprehensive carrying capacity of little difference.

③ The comprehensive carrying capacity of Yaan city ranks poorly, mainly reflecting in the resource subsystem, economic subsystem and social subsystem. As a well-known tourist city, Yaan city performs well in environment subsystem. Located at the edge of Sichuan Basin, Yaan city is inferior to Mianyang city and Deyang city in momentum of growth. Besides, a strong earthquake of 7.0 happened in 2013 in Yaan city, which was bound to influence the city's economic development.

④ Although the area of Chengdu ubran agglomeration is small, there are obvious classification features. As shown from the cluster tree hierarchical figure, the first layer is Chengdu city; the second layer being Deyang city, partial area of Leshan city, Mianyang city and Meishan city; the third layer being Suining city, Ziyang city and Yanan city. The result of the comprehensive carrying capacity of Chengdu urban agglomeration ranges from [0.08, 0.8], which differs greatly from Yaan city.

⑤ At present, except for Chengdu city, there is no megalopolis which has a population of one million. The urban system structure of Chengdu urban agglomeration is not reasonable. As the core city of the region, the leading role of Chengdu city is not strong enough. Although Chengdu is far ahead of other cities, the regional coordinated development pattern has not achieved. Most major cities in the urban agglomeration have not established a reasonable relationship between division of labor and cooperation, meanwhile the problems on industrial structure also exist, therefore, the integrated competition advantage of the urban agglomeration fails to be accomplished. The major problems lie in the following aspects: the lack of integration of internal coordination mechanism, the ineffective matching and linking of major infrastructure, a further step of perfection of system environment and unified market. In a word, the urbanization level is low, the development of service industry is lagging behind and the simultaneous development Four Modernizations is facing a lot of problems.

(3) A Dynamic Analysis of the Comprehensive Carrying Capacity of Chengdu Urban Agglomeration

① Chengdu city keeps stably the first place, which is inseparable with its core economic status. However, according to the coefficients of variation, the comprehensive carrying capacity has been performing a falling trend, from 0.9081 in 2009 to 0.8999 in 2010 to 0.7029 in 2013. Thus we need pay great attention to the changing situation.

② The ranking of the other seven cities have fluctuated. Generally speaking, Mianyang city and Deyang city occupy the front positions, while Suining city and Yaan city rank at the bottom, among which the comprehensive carrying capacity of Yaan city always ranks poorly.

③ The carrying capacity of resource subsystem takes the obvious advantage, whose coefficient of variation is higher than other subsystem. The major reason lies in the big weighting of two indexes, which are total water supply index of 0.1463 and total gas supply index of 0.1013. However, the social carrying capacity has become the obstacle of the city's comprehensive carrying capacity. For instance, the weighting of social subsystem index is low, among which the index of technology and education expenditure is only 0.1067 and the other indexes are lower than 0.1. From 2010, all the indexes decreased greatly, especially the index of unemployment, thus making the overall carrying capacity of social subsystem performed poorly. However, since 2010, the social carrying capacity of Chengdu urban agglomeration has grown significantly and has been maintaining a good upward trend.

136.5 Suggestion

136.5.1 Reasonable City Planning and City Size Controlling

The carrying capacity of social subsystem in Chengdu urban agglomeration is relatively weak. Population size has exerted great pressure on the carrying capacity of social subsystem. As a result, investment on infrastructure should be increased and rural labor force should be transferred to urban area in order to ease population pressure. Social carrying capacity includes a variety of aspects such as transportation, post and telecommunications, medical treatment as well as science and education, all of which are closely related to people's living standard and life happiness. In this sense, it is of great importance to plan city reasonably and control the rapid expansion of city size thus increase urban social carrying capacity.

136.5.2 To Optimize Industrial Upgrading and to Promote Employment Level

Another pressure of the social subsystem in Chengdu urban agglomeration is due to the number of unemployed persons. Taking Chengdu city for an instance, the number of unemployed was 139,600 in 2013, which was several times that of other cities. In recent days, Zeng Xiangquan, as director of China Research Institute mentioned that China was facing the second wave of laid-offs, which implied that the problem of employment tended to be serious and needed solving urgently.

The adjustment of industrial structure can accelerate flow and allocation of labor force among industries, promoting optimization of employment structure. First of all, secondary industry of little flexibility should be developed vigorously, promoting the development of tertiary industry. Meanwhile, new technology needs applying thus adopt the policy of "public entrepreneurship and mass innovation". Moreover, the development of tertiary industry can enhance the absorptive capability of employment. Due to its high elasticity, the rapid-developing tertiary industry can help to transform agricultural surplus labor.

136.5.3 To Improve the Quality of Urban Population and to Improve the Level of Social Services

According to the above analysis, two kinds of pressure are reflected in social subsystem; meanwhile, due to the weak support force, the carrying capacity of social subsystem is relatively poor. In this circumstance, it is of vital importance to take some measures to solve the problem. Firstly, workers' average wage needs increasing gradually to ensure people's living standard. Secondly, rapid establishment of medical infrastructure is necessary to improve the urban medical and health level. Thirdly, the quality of compulsory education should be enhanced for cultivating scientific and technological innovation talents; besides, the increasing expenditure on education and scientific research is also indispensable. Fourthly, transportation infrastructure also needs perfection thus improve use efficiency of public transport and roads.

136.5.4 To Increase Use Efficiency of Resources and to Allocate Resources Reasonably

The carrying capacity of resource subsystem in Chengdu urban agglomeration performs well therefore maintaining the well-developing situation is necessary. Within the urban agglomeration, green consumption and low carbon energy-saving life needs promoting. The government should provide some policy guidance and moderate reward. For water resource exerts the greatest influence on the carrying capacity of resource, the allocation and use of water resource should be attached great importance. In this case, we need to take measures to handle the issue. Firstly, we need to pay attention to the economical use of water resources and to strengthen the construction of water conservancy projects; besides, it is important to improve the repeat usage of water resources and to make full use of groundwater resources, all of which can help to achieve a comprehensive allocation of water resources.

136.5.5 To Mend Environment Pollution and to Strengthen the Construction of Eco Urban Agglomeration

Although Chengdu urban agglomeration performs well in the aspect of the carrying capacity of environment subsystem, enough environmental crisis awareness is also necessary. Located in the acid rain area, Sichuan province needs to make great effort to protect the industrial environment. Firstly, we need to increase the use efficiency of industrial coal in order to both control the emission and increase the governance rate of industrial sulfur dioxide. Moreover, circular economy needs implementing and household garbage needs classifying and recycling. Last but not the least, an increasing supply of environmental capital is also indispensable for mending the environment pollution and building a green city.

Acknowledgments This research is supported by the Ministry of education of Humanities and Social Science Project (15YJC630081); Sichuan Social Science Planning Project (Grant No. SC14C027) and the Sichuan System Science and Enterprise Development Research Center (Grant No. Xq14B08);

References

1. Arrow K, Bolin B et al (1995) Economic growth, carrying capacity, and the environment. Science 268(5210):520
2. Daily GC, Ehrlich PR (1996) Socioeconomic equity, sustainability, and earth's carrying capacity. Ecol Appl pp 991–1001
3. Hardin G (1986) Cultural carrying capacity: a biological approach to human problems. BioScience 36(9):599–606
4. Odum EP, Barrett GW (1971) Fundamentals of ecology, vol 3. Saunders, Philadelphia
5. Park RE, Burgess EW, Janowitz M (1969) Introduction to the science of sociology. Greenwood Press, Connecticut
6. Price D (1999) Carrying capacity reconsidered. Popul Environ 21(1):5–26
7. UNESCO F (1985) Carrying capacity assessment with a pilot study of Kenya: A resource accounting methodology for sustainable development. Paris and Rome

Chapter 137
Robust Estimation of Capability Index

Syed Ejaz Ahmed, Abdulkadir Hussein and R. Ghori

Abstract The process capability indices (PCI) have been popular in the manufacturing environment to quantify the capability of an industrial process. In this paper, a robust estimator of the C_p index, based on the Gini mean difference statistic, is proposed. The performance of the proposed estimator and its associated confidence intervals are compared to those associated with the classical estimator based on the sample standard deviation. The use of the new method is illustrated by application to data set about membrane thickness of STN color pixels.

Keywords Gini mean difference · Process capability index · Asymptotic analysis · Asymptotic relative efficiency · Bootstrap confidence intervals

137.1 Introduction

The concept of process capability indices (PCI) has emerged to in the past four decades as a way of quantifying process adequacy. A commonly used index is

$$C_p = \frac{U-L}{6\sigma} = \frac{d}{6\sigma}; \quad d = U - L, \tag{137.1}$$

where U and L (or, equivalently, USL and LSL) are the upper and lower specification limits, respectively and σ is the standard deviation of the measurement of interest. Despite the huge research contributions and application activities, there are still

S. Ejaz Ahmed (✉)
Department of Mathematics and Statistics, Brock University, Brock,
St. Catharines, ON L2S 3A1, Canada
e-mail: sahmed5@brocku.ca

A. Hussein
University of Windsor, Windsor, ON, Canada

R. Ghori
Merck and Co. (MSD), Rahway, NJ, USA

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_137

some important unsolved issues in the area of PCI. The most important among these unsolved issues is the effect of violation of normality assumption.

The C_p index defined in Eq. (137.1) assumes that the measurement of interest is normally (or near normally) distributed. Under this assumption, the C_p index can be interpreted as the ratio of desired specification limits to the "Actual" process limits containing 99.7 % of the measurements. In other words, an Engineer desires that 99.7 % of the measurements should be within (U, L), leaving out only a proportion of 0.003 % outside these limits (nonconforming proportion).

The consequences of non-normality and its remedies in the context of capability indices have been discussed by many authors. For example, Krishnamoorthi and Khatwani [6] proposed a capability index which handles normal and nonnormal characteristics by first fitting the data to a Weibull distribution. Ahmed [2] developed a robust pooled estimator of a capability index for arbitrary multivariate population. Nahar et al. [9] and Chang et al. [3] considered process capability indices for skewed populations. Process capability analysis, when observations are autocorrelated, is investigated by Noorossana [10] using time series modeling and regression analysis. More recently, Senvar and Kahraman [13] proposed a fuzzy set theory for capability index for non-normal processes, while Abbasi [1] used neural networks for the same purpose. On the other hand, Pearn et al. [11] compared Bayesian and non-Bayesian approaches to estimating PCIs, Polansky [12] discussed a non-parametric Bayesian approach. The case of autocorrelated process observations was considered by Lundkvist et al. [8].

The assumption of normality is realistic in some situations and allows researchers to built the estimators of indices on the bases of sample standard deviation. These estimators are easy to interpret and their sampling distributions are mathematically tractable. In situations where the normality assumption is not justifiable and the observed distribution of the characteristic of interest suffers from unusually large or small observations, the estimators of capability indices based on the sample standard deviation are known to have unusually higher/lower sampling variations. Therefore, a capable process may be declared as incapable and viceversa. As a result, robust estimators of standard deviation like *modified maximum likelihood estimator*, *winsorized standard deviation* and *M-estimator*, among many, were used to solve the problem. However, none of the above mentioned methods yielded satisfactory results [5]

In this paper, we use the Gini Mean Difference (GMD) as estimator of σ in the C_p index. The GMD, defined by

$$G = E|X - Y|, \tag{137.2}$$

where X, Y are independent copies from a distribution F, has been used as a measure of population variation. For a sample $X_1, X_2, \ldots, X_n$ from F, the Gini mean difference statistic, g, is the natural, unbiased estimator of G,

$$g = \frac{2}{n(n-1)} \sum_{i<j} |X_i - X_j|. \tag{137.3}$$

In this article, a robust estimator of the C_p index based on the statistic g will be studied and compared to the standard C_p estimator based on the sample standard deviation, s.

The paper is organized as follows. In Sect. 137.2, the asymptotic normality of the proposed estimator is established, some of its large-sample statistical properties are investigated and an unbiased estimator of its asymptotic variance is provided. In Sect. 137.3, we discuss some theoretical properties of the relative efficiency (ARE) of the proposed estimator with respect to the classical estimator based on sample standard deviation. Monte Carlo simulations are used to examine the ARE for moderate to large samples. The problem of interval estimation is addressed in Sect. 137.4. In addition to asymptotic confidence intervals, three kinds of bootstrap intervals, namely, standard bootstrap, bootstrap-t and BCa are constructed and compared. In Sect. 137.5, we apply the methods to a data set.

137.2 Point Estimation

As mentioned earlier the GMD is a parameter, defined by Eq. (137.2), its natural plug-in estimator is given by Eq. (137.3). We note that, in general, $G \neq \sigma$ and therefore $Eg \neq \sigma$, rather there is a distribution-dependent coefficient, $c = c_F$ such that $G_c = G/c = \sigma$ and hence, $EG_c = \sigma$. The coefficient c is constant for some families of distributions, for example, if F is the normal distribution then $c = 2/\sqrt{\pi}$. However, for a mixture of two normal distributions of the form,

$$F(x) = p\Phi(x) + (1-p)\Phi\left(\frac{x-\mu}{\sigma}\right), \tag{137.4}$$

where c is no longer constant for all members of the family. In this case, c is given by

$$c = \frac{2}{\sqrt{\pi}} \frac{\left[p^2 + (1-p)^2\sigma + p(1-p)\sqrt{2+2\sigma^2}\right]}{\sqrt{p+(1-p)\sigma^2}}. \tag{137.5}$$

By using the Cauchy-Schwartz inequality we have

$$0 < c < \sqrt{2}, \tag{137.6}$$

for any distribution F.

Under some regularity conditions, the asymptotic normality of g can be established as

$$\sqrt{n}(g - G) \xrightarrow{\mathscr{D}} N(0, \tau^2), \tag{137.7}$$

where $\xrightarrow{\mathscr{D}}$ means convergence in distribution,

$$\tau^2 = 4[\mathscr{F} - G^2], \tag{137.8}$$

and $\mathscr{F} = E(|(X_1 - X_2)(X_1 - X_3)|)$.

An unbiased estimator of τ^2 is

$$\hat{\tau}^2 = 4\left[\hat{\mathscr{F}} - \widehat{(G^2)}\right], \tag{137.9}$$

where

$$\hat{\mathscr{F}} = \frac{1}{n(n-1)(n-2)} \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n} |x_i - x_j||x_i - x_k| - \frac{2S^2}{n-2}, \tag{137.10}$$

$$\widehat{(G^2)} = \frac{n(n-1)}{(n-2)(n-3)} g^2 - \frac{4}{(n-3)}\hat{\mathscr{F}} - \frac{4}{(n-2)(n-3)} S^2. \tag{137.11}$$

In the following lemma we prove that $\hat{\tau}^2$ is a consistent estimator of τ^2.

Lemma 137.1 *If the fourth moment of the process distribution F exist then,* $\hat{\tau}^2 \xrightarrow{P} \tau^2$ *as* $n \to \infty$.

Proof As both $\widehat{G^2}$ and $\hat{\mathscr{F}}$ are functions of U-statistics with symmetric kernels, their consistency follow from the strong law of large numbers for U-statistics Serfling 1980 (p 190)). Since $\widehat{G^2} \xrightarrow{P} G^2$ and $\hat{\mathscr{F}} \xrightarrow{P} \mathscr{F}$ as $n \to \infty$, the desired result follows by standard large-sample theory [7]. This completes the proof.

137.2.1 Robust Estimation

The estimator of the C_p based on the Gini mean difference statistic can be defined as

$$\hat{C}_p^g = d/(6g_c), \tag{137.12}$$

where $g_c = g/c$.

The following theorem gives the asymptotic distribution of $\hat{C}_p^g$.

Theorem 137.1 *If* $E_F(X^2) < \infty$ *then,*

$$\sqrt{n}(\hat{C}_p^g - C_p) \xrightarrow{\mathscr{D}} N(0, \gamma_g^2), \tag{137.13}$$

where $\gamma_g^2 = (C_p)^4(6/(dc))^2\tau^2$.

Proof The proof follows by a simple application of the delta method and from Eq. (137.7).

From this theorem and the results of the previous section, one can deduce that a consistent estimator of the variance of the asymptotic distribution of $\hat{C}_p^g$ is

$$\hat{\gamma}_g^2 = \frac{6(\hat{C}_p^g)^4\hat{\tau}^2}{dc}.$$

137.3 Asymptotic Relative Efficiency (ARE)

The performance of two competing estimators is usually measured by the so called *asymptotic relative efficiency (ARE)* defined as the ratio of their asymptotic variances. In the current context, the asymptotic efficiency of $\hat{C}_p^g$ relative to $\hat{C}_p^s = d/6S$ is given by

$$ARE(\hat{C}_p^g : \hat{C}_p^s) = \frac{\gamma_g^2}{\gamma_s^2} = \frac{(C_p)^4(6/(dc))^2\tau^2}{(1/4)(\beta_2 - 1)C_p^2},$$

where $\gamma_g^2 = (1/4)(\beta_2 - 1)C_p^2$ is the variance of the asymptotic distribution of $\hat{C}_p^s$, and β_2 is the kurtosis of the distribution of the characteristic of interest.

In the following lemma we establish an upper bound for the asymptotic relative efficiency of $\hat{C}_p^g$ with respect to $\hat{C}_p^s$

Lemma 137.2 *For a given value of β_2,*

$$ARE(\hat{C}_p^g : \hat{C}_p^s) \le 16(2/c^2 - 1)/(\beta_2 - 1). \tag{137.14}$$

Proof By using the Hölder's inequality

$$\begin{aligned}\mathscr{F} &= E|(X_1 - X_2)(X_1 - X_3)| \\ &\le \left(E|X_1 - X_2|^2\right)^{1/2}\left(E|X_1 - X_3|^2\right)^{1/2} \\ &= (2\sigma^2)^{1/2}(2\sigma^2)^{1/2} = 2\sigma^2.\end{aligned} \tag{137.15}$$

As a consequence of Eq. (137.15) we find that

$$\begin{aligned}0 < \gamma_g^2 &\le C_p^4\left(\frac{6}{dc}\right)^2 4(2\sigma^2 - G^2) \\ &= C_p^4\left(\frac{6}{dc}\right)^2 4(2/c^2 - 1)G^2 \\ &= 4(2/c^2 - 1)C_p^2.\end{aligned} \tag{137.16}$$

Hence, from Eq. (137.16), the asymptotic relative efficiency of $\hat{C}_p^g$ with respect to $\hat{C}_p^s$ is bounded above by $16(2/c^2 - 1)/(\beta_2 - 1)$, which completes the proof.

From this lemma, it follows that a sufficient condition for $\hat{C}_p^g$ to be asymptotically more efficient than $\hat{C}_p^s$ is

$$c^2(\beta_2 + 15) \geq 32. \tag{137.17}$$

We name $c^2(\beta_2 + 15) \geq 32$ the *dominance inequality (DI)*, since it specifies a range in the parameter space induced by β_2 and c in which the performance of $\hat{C}_p^g$ is relatively superior to that of $\hat{C}_p^s$. Indeed, when $c^2(\beta_2 + 15) \in I$, where $I = [32, \infty)$, then $\hat{C}_p^g$ is relatively more efficient than $\hat{C}_p^s$. However, outside the this interval, that is, $c^2(\beta_2 + 15) \in (0, 32)$, no definite conclusion can be drawn since the reliability of DI cannot be determined analytically. Further, the interval also depends on the value of c, which depends on the shape of process distribution. If the process population is normal then $c = 2/\sqrt{\pi}$ and β_2 is 3. This makes LHS of DI equal to 22.918. In this case DI is not informative. However direct calculations show that asymptotically $\hat{C}_p^s$ is slightly better than $\hat{C}_p^g$ when the underlying distribution is normal.

As we are only interested in slight deviations from normality, in all the simulation experiments in this study, we will assume that $c = 2/\sqrt{\pi}$.

137.3.1 Simulated Relative Efficiency (SRE)

To assess the relative performance of the estimators $\hat{C}_p^g$ and $\hat{C}_p^s$, a simulation study is conducted. The class of mixture normal distributions given by Eq. (137.4), with $\mu = 0$, is employed. One thousand samples of sizes $n = 15, 20, 30, 50, 100$ are taken and mean square error is calculated using the following formula:

$$MSE_s(\hat{\theta}) = b^{-1} \sum_{i=1}^{b} (\hat{\theta}_i - 1)^2$$

where $\hat{\theta}$ stands for either $\hat{C}_p^s$ or $\hat{C}_p^g$ estimated at each run of the $b = 1000$ Monte Carlo simulations. Finally the simulated relative *MSE* is defined as

$$SRE = \frac{MSE(\hat{C}_p^S)}{MSE(\hat{C}_p^g)}.$$

The results of the simulations are tabulated in Table 137.1. We can seen from the tabulated values that $\hat{C}_p^g$ outperformed $\hat{C}_p^s$ in almost all cases where the underlying distribution is not perfectly normal. A percentage improvement up to 43 % is observed when sample size was 100. In small samples, even with perfect normality,

Table 137.1 Simulated relative efficiency of $\hat{C}_p^s$ to $\hat{C}_p^g$ (ARE)

The % of the contamination, 1-p						
σ	5 %	4 %	3 %	2 %	1 %	0 %
$n = 15$						
2	1.05	1.06	1.08	1.06	1.04	1.05
3	1.13	1.12	1.10	1.11	1.07	1.07
4	1.22	1.18	1.17	1.15	1.09	1.05
5	1.25	1.24	1.24	1.17	1.15	1.04
6	1.27	1.31	1.24	1.22	1.12	1.07
$n = 20$						
2	1.04	1.05	1.04	1.04	1.06	1.03
3	1.21	1.20	1.13	1.09	1.07	1.04
4	1.31	1.27	1.23	1.19	1.15	1.01
5	1.33	1.37	1.30	1.30	1.17	1.04
6	1.41	1.42	1.39	1.35	1.23	1.06
$n = 30$						
2	1.09	1.05	1.06	1.05	1.04	1.00
3	1.32	1.29	1.22	1.19	1.08	1.01
4	1.44	1.47	1.46	1.36	1.23	1.00
5	1.58	1.59	1.55	1.51	1.30	1.01
6	1.59	1.64	1.62	1.60	1.39	1.01
$n = 50$						
2	1.08	1.13	1.07	1.04	1.04	0.99
3	1.46	1.44	1.39	1.25	1.17	0.99
4	1.66	1.67	1.61	1.55	1.40	1.01
5	1.83	1.87	1.95	1.89	1.58	1.01
6	1.91	1.95	1.95	2.00	1.86	1.01
$n = 100$						
2	1.18	1.15	1.10	1.08	1.04	1.00
3	1.63	1.67	1.60	1.48	1.28	0.98
4	1.92	1.98	2.02	2.06	1.75	1.00
5	2.09	2.14	2.27	2.29	2.23	0.99
6	2.17	2.26	2.54	2.63	2.45	0.99

the performance of $\hat{C}_p^g$ is better than $\hat{C}_p^s$. Under perfect normality (see the column headed by 0 %), where the performance of $\hat{C}_p^s$ is better than $\hat{C}_p^g$, with large sample size $n = 100$, the ratio of their asymptotic variances is $ARE = 0.980$.

137.4 Confidence Intervals

As mentioned earlier, the result in (137.13) can be used to construct large sample confidence interval. However, since the variance of $\hat{C}_p^g$ depends on parameter C_p, a direct asymptotic interval based on (137.13) would not perform well. In order to improve the asymptotic interval's performance, we used a variance stabilizing transformation and the resulting asymptotic 95 % confidence interval (referred to as ASY) is:

$$\frac{c}{g + z_{\alpha/2}\sqrt{\hat{\tau}/n}} \leq C_p \leq \frac{c}{g - z_{\alpha/2}\sqrt{\hat{\tau}/n}}, \tag{137.18}$$

where $c = 2/\sqrt{\pi}$ and $z_{\alpha/2}$ is the upper $(\alpha/2)^{th}$ quantile of the standard normal distribution.

A simulation study is conducted to compare the performance of the asymptotic interval given by Eq. (137.18) to the interval based on the benchmark estimator, $\hat{C}_p^s$. Four other bootstrapping techniques are also used to construct confidence intervals. Those are, standard bootstrap (SBS), bootstrap-t (TBA) and bias corrected accelerated (BCa) methods. As a benchmark to compare all the intervals to, we produced empirical confidence intervals (EMP) by simply simulating the quantiles of the sampling distribution of the estimator of interest ($\hat{C}_p^g$ or $\hat{C}_p^S$).

The variance of the asymptotic distribution of $\hat{C}_p^s$ depends on the kurtosis parameter, β_2, for which no good estimator exists, especially in non-normal distributions. Therefore, in addition to the above five confidence intervals, a sixth interval (AST) is constructed by using the true value of the kurtosis parameter. The intention was to use such interval to asses the impact that estimation of the kurtosis has on the performance of the intervals. In all the simulations, we took the true value of the capability index to be $C_p = 1$.

Each block in Tables 137.2, 137.3, 137.4 and 137.5 corresponds to a combination of n and $N_m(p, \mu, \sigma)$, where N_m stands for two component mixture normal distribution. Within each block, the following information for six different intervals is presented.

- Average or estimated lengths of the confidence intervals based on $\hat{C}_p^s$ and $\hat{C}_p^g$, denoted by avl$s$ and avl$g$.
- The probability of covering 1 for the confidence intervals based on $\hat{C}_p^s$ and $\hat{C}_p^g$, denoted by cpro$s$ and cpro$g$

The six intervals are: empirical EMP, asymptotic ASY, asymptotic with the true kurtosis AST, basic bootstrap SBS, bootstrap-t TBS, and bias corrected and accelerated bootstrap BCa.

Table 137.2 The symbols avls, cpros and avlg, cprog denote average interval lengths and coverage probabilities for the standard and robust method, respectively

Type	Asymptotic				Type	Bootstrap			
	avls	avlg	cpros	cprog		avls	avlg	cpros	cprog
$\sigma = 1, p = 0.99, \beta_2 = 3$									
EMP	0.89	0.93	0.95	0.95	SBS	0.93	0.99	0.96	0.96
ASY	0.66	0.83	0.87	0.85	TBS	0.95	0.87	0.93	0.91
AST	0.76	0.83	0.93	0.85	BCa	0.67	0.66	0.9	0.88
$\sigma = 2, p = 0.99, \beta_2 = 3.25$									
EMP	0.88	0.88	0.95	0.95	SBS	0.92	0.98	0.95	0.96
ASY	0.67	0.87	0.87	0.86	TBS	0.99	0.9	0.93	0.91
AST	0.81	0.87	0.94	0.86	BCa	0.67	0.66	0.9	0.88
$\sigma = 2, p = 0.98, \beta_2 = 3.47$									
EMP	0.91	0.9	0.95	0.95	SBS	0.95	1	0.95	0.96
ASY	0.67	0.87	0.86	0.85	TBS	0.96	0.88	0.92	0.89
AST	0.82	0.87	0.94	0.85	BCa	0.67	0.66	0.89	0.87
$\sigma = 3, p = 0.98, \beta_2 = 5.8$									
EMP	0.92	0.87	0.95	0.95	SBS	0.94	0.99	0.95	0.96
ASY	0.66	0.79	0.84	0.86	TBS	0.99	0.9	0.91	0.90
AST	1.13	0.79	0.96	0.86	BCa	0.68	0.67	0.88	0.86
$\sigma = 4, p = 0.99, \beta_2 = 8.05$									
EMP	0.99	0.88	0.95	0.95	SBS	0.96	1	0.96	0.97
ASY	0.66	0.93	0.85	0.86	TBS	0.99	0.89	0.92	0.90
AST	1.38	0.93	0.97	0.86	BCa	0.68	0.67	0.89	0.86

Sample size $n = 15$ and various σ, p and kurtosis values β_2 for the mixture (137.4) and the six C. Is discussed in the text were used

For small sample size, $n = 15$, we see from Table 137.2 that, under perfect normality ($\beta = 3$), the asymptotic s-intervals are shorter than the asymptotic g-intervals and both are shorter than their corresponding empirical EMP intervals. The asymptotic s-interval with the true kurtosis covers better than its version with estimated kurtosis. In terms of coverage probabilities, the s-intervals are better than the g-intervals. As the kurtosis increases, while holding the contamination fixed at $p = 0.99$, the asymptotic g-intervals get slightly better in terms of coverage probabilities, but still worse than the s-intervals. However, it is to be noted that both s- and g-intervals give coverage probabilities lower than the nominal by about 10 %.

The asymptotic s-intervals, using the true kurtosis, continue to do better in terms of coverage probabilities at the cost of slightly longer interval lengths even in highly leptokurtic populations. As for the bootstrapped intervals, SBS intervals do much better than the other two bootstrap intervals in terms of coverage with slightly longer

Table 137.3 Simulations results for $n = 20$

Type	Asymptotic				Type	Bootstrap			
	avls	avlg	cpros	cprog		avls	avlg	cpros	cprog
$\sigma = 1, p = 0.99, \beta_2 = 3$									
EMP	0.70	0.71	0.95	0.95	SBS	0.75	0.78	0.94	0.97
ASY	0.59	0.71	0.90	0.90	TBS	0.78	0.74	0.95	0.94
AST	0.65	0.71	0.94	0.90	BCa	0.59	0.59	0.90	0.90
$\sigma = 2, p = 0.99, \beta_2 = 3.25$									
EMP	0.74	0.71	0.95	0.95	SBS	0.73	0.77	0.95	0.95
ASY	0.58	0.71	0.90	0.91	TBS	0.75	0.71	0.95	0.93
AST	0.67	0.71	0.94	0.91	BCa	0.59	0.59	0.90	0.90
$\sigma = 2, p = 0.98, \beta_2 = 3.47$									
EMP	0.71	0.70	0.95	0.95	SBS	0.74	0.78	0.95	0.96
ASY	0.58	0.72	0.87	0.89	TBS	0.77	0.72	0.94	0.91
AST	0.70	0.72	0.95	0.89	BCa	0.59	0.59	0.90	0.89
$\sigma = 3, p = 0.98, \beta_2 = 5.80$									
EMP	0.86	0.76	0.95	0.95	SBS	0.76	0.78	0.94	0.94
ASY	0.59	0.76	0.86	0.91	TBS	0.80	0.74	0.92	0.91
AST	0.95	0.76	0.94	0.91	BCa	0.60	0.60	0.89	0.88
$\sigma = 4, p = 0.99, \beta_2 = 8.05$									
EMP	0.84	0.78	0.95	0.95	SBS	0.76	0.79	0.94	0.94
ASY	0.59	0.75	0.85	0.89	TBS	0.83	0.76	0.94	0.92
AST	1.16	0.75	0.96	0.89	BCa	0.60	0.60	0.89	0.89

intervals. The performance of the s and g intervals are approximately same for the SBS bootstrapping. BCa intervals are the worst in coverage and of course they have the shortest interval lengths among the bootstrapped intervals. The TBS intervals work reasonably well with lower-than-nominal coverage probabilities of about 2–5 % and much shorter lengths than the SBS intervals. In general, for small sample size, the bootstrapped intervals do better than the asymptotic intervals (except when true kurtosis is used). Again, the s bootstrapped intervals are slightly better than the g bootstrapped intervals in terms of coverage (about 0–2 % better coverage) but the latter are significantly shorter.

For $n = 20$, the asymptotic s-interval still, substantially, under-covers whereas the g-intervals get better (undercoverage of about 5 %) and this pattern becomes clearer as the kurtosis, β_2, increases, whereas under perfect normality, the g and s intervals are similar in coverage but the s-intervals are shorter. As for the bootstrapped intervals,

Table 137.4 Simulations results for $n = 30$

Type	Asymptotic				Type	Bootstrap			
	avls	avlg	cpros	cprog		avls	avlg	cpros	cprog
$\sigma = 1, p = 0.99, \beta_2 = 3$									
EMP	0.51	0.52	0.95	0.95	SBS	0.55	0.58	0.95	0.95
ASY	0.49	0.55	0.93	0.93	TBS	0.58	0.56	0.95	0.93
AST	0.52	0.55	0.96	0.93	BCa	0.48	0.49	0.90	0.90
$\sigma = 2, p = 0.99, \beta_2 = 3.25$									
EMP	0.56	0.55	0.95	0.95	SBS	0.56	0.58	0.95	0.95
ASY	0.49	0.55	0.91	0.92	TBS	0.60	0.58	0.93	0.93
AST	0.54	0.55	0.94	0.92	BCa	0.48	0.49	0.89	0.90
$\sigma = 2, p = 0.98, \beta_2 = 3.47$									
EMP	0.57	0.54	0.95	0.95	SBS	0.56	0.59	0.95	0.95
ASY	0.49	0.56	0.90	0.92	TBS	0.59	0.57	0.93	0.92
AST	0.56	0.56	0.94	0.92	BCa	0.48	0.49	0.89	0.89
$\sigma = 3, p = 0.98, \beta_2 = 5.80$									
EMP	0.68	0.63	0.95	0.95	SBS	0.59	0.60	0.92	0.93
ASY	0.50	0.59	0.86	0.91	TBS	0.67	0.61	0.92	0.91
AST	0.76	0.59	0.93	0.91	BCa	0.49	0.50	0.88	0.88
$\sigma = 4, p = 0.99, \beta_2 = 8.05$									
EMP	0.70	0.60	0.95	0.95	SBS	0.59	0.60	0.94	0.94
ASY	0.50	0.59	0.87	0.93	TBS	0.66	0.59	0.91	0.91
AST	0.94	0.59	0.96	0.93	BCa	0.50	0.50	0.89	0.89

the SBS is the best in terms of both length and coverage. The coverage of the s and g bootstrapped SBS intervals are similar but the s intervals are shorter.

For larger sample sizes, $n = 100$, we see from Table 137.5 that the asymptotic s-intervals perform poorly in terms of coverage (undercover about 6 %) for leptokurtic process populations, whereas the asymptotic g-interval is almost perfect both in lengths and in coverage (taking the empirical EMP intervals as reference). In perfectly normal population, $\beta_2 = 3$, the s- and g-intervals perform equally well both in lengths and in coverage. Bootstrap g-intervals are shorter and better in coverage than their s counterparts as kurtosis increases. SBS and TBS bootstrap intervals perform similar to each other. In general, as kurtosis increases, the bootstrap s-interval are better than the asymptotic intervals of s in coverage, whereas the bootstrap g-intervals perform poorly as compared to their asymptotic counterparts.

Table 137.5 Simulations results for $n = 100$

Type	Asymptotic				Type	Bootstrap			
	avls	avlg	cpros	cprog		avls	avlg	cpros	cprog
$\sigma = 1, p = 0.99, \beta_2 = 3$									
EMP	0.28	0.29	0.95	0.95	SBS	0.28	0.29	0.94	0.94
ASY	0.27	0.29	0.95	0.94	TBS	0.29	0.29	0.96	0.96
AST	0.28	0.29	0.95	0.94	BCa	0.27	0.28	0.94	0.94
$\sigma = 2, p = 0.99, \beta_2 = 3.25$									
EMP	0.29	0.29	0.95	0.95	SBS	0.29	0.29	0.93	0.94
ASY	0.28	0.29	0.94	0.95	TBS	0.30	0.30	0.93	0.93
AST	0.29	0.29	0.95	0.95	BCa	0.28	0.28	0.93	0.93
$\sigma = 2, p = 0.98, \beta_2 = 3.47$									
EMP	0.30	0.29	0.95	0.95	SBS	0.29	0.29	0.93	0.93
ASY	0.28	0.29	0.92	0.94	TBS	0.31	0.30	0.91	0.91
AST	0.30	0.29	0.93	0.94	BCa	0.28	0.28	0.91	0.91
$\sigma = 3, p = 0.98, \beta_2 = 5.8$									
EMP	0.35	0.30	0.95	0.95	SBS	0.33	0.31	0.89	0.91
ASY	0.32	0.31	0.88	0.94	TBS	0.39	0.33	0.91	0.92
AST	0.40	0.31	0.90	0.94	BCa	0.32	0.30	0.82	0.80
$\sigma = 4, p = 0.99, \beta_2 = 8.05$									
EMP	0.43	0.32	0.95	0.95	SBS	0.34	0.31	0.91	0.92
ASY	0.33	0.32	0.89	0.96	TBS	0.42	0.34	0.90	0.93
AST	0.49	0.32	0.90	0.96	BCa	0.33	0.31	0.86	0.89

Therefore, when n is large, the asymptotic intervals based on the Gini statistic perform better in terms of coverage and interval lengths in comparison to the asymptotic s-intervals, the bootstrapped s-intervals, and the bootstrapped g-intervals. The asymptotic g-intervals give similar coverage and lengths as the s asymptotic intervals under perfect normality for large sample sizes.

In conclusion, we recommend that the g asymptotic intervals be used when normality of the underlying process is suspected and the sample size is reasonably large.

137.5 Case Study

In this section, we use a real data set to illustrate the estimator and confidence intervals proposed in the paper. The data set we use is from a case study published in Chen and Chen [4]. The case study is concerned with color STN (Super Twist Nematic)

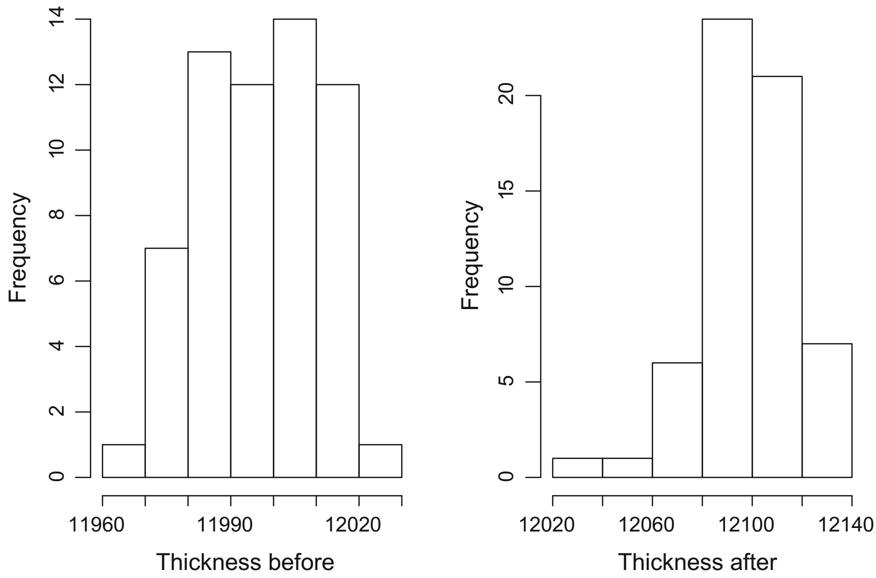


Fig. 137.1 Membrane thickness for the STN example. Data after calibration look more nonnormal than data before

displays product taken from a manufacturing industry located in the Taichung economic processing zone, Taiwan. According to Chen and Chen [4], Color STN displays are created by adding color filters to traditional monochrome STN displays. Controlling the light through the color filter allows different colors to be produced through combinations of the primary colors ($R < B$ and G). The membrane thickness of each pixel is the quantity of interest. The data reported in Chen and Chen [4] contain 60 measurements of the thickness before and after calibrating the machines. The specification limits are $12{,}000 \pm 500A_0$ ($1A_0 = 10^{-7}$ mm), that is, the upper and the lower specification limits are set to $\mathrm{USL} = 12{,}500$, $\mathrm{LSL} = 11{,}500$.

The post-calibration data are more apparently nonnormal than data before calibration (see Fig. 137.1). The estimators ad the host of confidence intervals discussed in earlier section are computed for these data and the results are reported in Table 137.6 with (+) indicating that the length of the Gini index based confidence intervals are shorter than the corresponding intervals based on the sample standard deviation. We can see that when the data deviates from normality (i.e., data after calibration) the $\hat{C}_p^g$ and allied confidence intervals do better in terms of interval length.

Table 137.6 Results for CP

Before						After					
Type	Estimate		95 % *CI*		Length		Type	Estimate	95 % *CI*		Length
			Lower	Upper					Lower	Upper	
CPg	SBS		6.573	10.342	3.769	CPg	SBS		9.987	13.199	3.212
	TBS		6.359	10.059	3.700		TBS		10.367	13.196	2.829(+)
	BCa		6.935	10.316	3.382 (+)		BCa		10.381	13.251	2.870(+)
	ASY	8.690	6.883	10.497	3.614		ASY	11.838	10.414	13.262	2.848 (+)
CPs	SBS		6.567	10.286	3.719	CPs	SBS		10.363	13.556	3.192
	TBS		6.303	9.985	3.681		TBS		10.533	13.769	3.236
	BCa		6.852	10.296	3.444		BCa		10.712	13.675	3.531
	ASY	8.594	6.829	10.360	3.531		ASY	12.152	10.662	13.642	2.980

137.6 Summary and Conclusions

In this article, an estimator of C_p based on the Gini mean difference statistic is defined and its asymptotic normality is established. Asymptotic relative efficiency of the proposed estimator is assessed analytically and by using Monte Carlo simulations. Another simulation study is conducted to assess the relative performances of asymptotic and bootstrapped intervals based on $\hat{C}_p^g$ and $\hat{C}_p^s$, the benchmark standard estimator of the C_p index.

Results from both simulation studies suggest that the performance of $\hat{C}_p^g$ is better even when the sample size is small. In terms of efficiency, $\hat{C}_p^g$ gives a reduction of up to 43 % in the MSE as compared to $\hat{C}_p^s$. The asymptotic interval did not performed as good as its bootstrapped versions for small sample sizes, but for moderate and large sample sizes it outperformed the bootstrap intervals. In conclusion we recommend that, for reasonably large sample sizes, the proposed $\hat{C}_p^g$ estimator and its associated asymptotic confidence interval be used instead of the standard $\hat{C}_p^s$ estimator.

It is worth mentioning that there are many situations where taking a large sample is more economical than taking frequent samples. The requirement of a large sample size may not be stringent: Rodriguez reported that some organizations have required tests of normality to accompany reported indexes or have mandated large sample sizes (as large as 120 in one company). For economic considerations, if the cost associated with producing a defective item is low, then larger, less frequent samples are better than smaller, more frequent ones. In addition, the rate of production also influences the choice of the sample size. For example, if a plant can produce 80,000 units per hour, then it does not take an appreciable difference in time to collect a sample size of 100 as compared to a sample of size 20. Keeping the resource implications in mind, if per unit inspection and testing costs are not excessively high, then high-speed production processes are often monitored with moderately large sample sizes. The overall cost of sampling may be reduced by judiciously collecting a relatively large amount of inexpensive data to increase the accuracy of the estimator. Thus, the goal of finding large sample methods for such problems seems well worth achieving.

References

1. Abbasi B (2009) A neural network applied to estimate process capability of non-normal processes. Expert Syst Appl 36(2):3093–3100
2. Ejaz Ahmed S (2005) Assessing the process capability index for non-normal processes. J Stat Plan Inference 129(1):195–206
3. Chang YS, Choi IS, Bai DS (2002) Process capability indices for skewed populations. Q Reliab Eng Int 18(5):383–393
4. Chen JP, Chen K (2004) Comparison of two process capabilities by using indices Cpm: an application to a color stn display. Int J Q Reliab Manag 21(1):90–101
5. Kocherlakota S, Kocherlakota K (1994) Confidence intervals for the process capability ratio based on robust estimators. Commun Stat-Theory Methods 23(1):257–276

6. Krishnamoorthi K, Khatwani S (2000) A capability index for all occasions. In: ASQ world conference on quality and improvement proceedings, American society for quality, p 77
7. Lehmann EL (1999) Elements of large-sample theory. Springer science and business media. Springer, Berlin
8. Lundkvist P, Vännman K, Kulahci M (2012) A comparison of decision methods for C-pk when data are autocorrelated. Qual Eng 24(4):460–472
9. Nahar P, Hubele N, Zimmer L (2001) Assessment of a capability index sensitive to skewness. Qual Reliab Eng Int 17(4):233–241
10. Noorossana R (2002) Process capability analysis in the presence of aautocorrelation. Qual Reliab Eng Int 18:75–77
11. Pearn WL, Wu CC, Wu CH (2015) Estimating process capability index Cpk: classical approach versus bayesian approach. J Stat Comput Simul 85(10):2007–2021
12. Polansky AM (2014) Assessing the capability of a manufacturing process using nonparametric bayesian density estimation. J Qual Technol 46(2):150
13. Senvar O, Kahraman C (2014) Fuzzy process capability indices using clements' method for non-normal processes. J Mult-Valued Logic Soft Comput 22(1):95–121

Chapter 138
Green Credit Policy and the Maturity of Corporate Debt

Liangcheng Wang and Yi Zhu

Abstract This paper is based on strict credit environment under the background of green credit policy in China. It focuses on the change in the maturity of corporate debt of polluted enterprises. The research finds that long-term loan of polluted enterprises is significantly dropped after the policy. Extensive research shows that after green credit policy, long-term loan of state-owned polluted enterprises is higher than private polluted enterprises. The result shows that under hash green credit environment, banks are more cautious about loans to polluted enterprises. In terms of the maturity of corporate debt, polluted enterprises are subject to severe constraints in general. However, state-owned polluted enterprises face fewer restrictions due to credit discrimination. Generally, green credit policy has achieved some success and it provides institution guarantee for sustainable economic development in China.

Keywords Green credit policy · Polluted enterprises · Debt maturity · Property

138.1 Introduction

With the introduction of Equator Principles, there is a widespread concern over the issue of social responsibilities of commercial banks. Equator Principles provide a minimum standard of environmental protection and social norms for commercial bank credit. Since then commercial banks have began to integrate sustainability issues into their finance operations [8]. China's commercial banks have only focused on their own economic interests in past decades and ignored social responsibility. Hence, many credit programs resulted in adverse environmental and social problems. In July 2007, Ministry of Environmental Protection, People's Bank of China, China Banking Regulatory Commission jointly issued "Advice on Implementation of Environmental Policies and Regulations to Prevent Credit Risks", namely green credit policy. The

L. Wang (✉) · Y. Zhu
School of Business, Sichuan University, Chengdu 610064,
People's Republic of China
e-mail: liawang@aliyun.com

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_138

policy requires that banks should review environmental compliance of enterprises when providing loans to them. Environmental compliance should be a necessary condition to get credit approval. The policy aims to reduce non-performing credit due to environmental violation by constraining credit to polluted enterprises. Green credit policy proposed requirements for commercial banks in terms of environmental social responsibility. Does green credit policy really take effect? Existing domestic research rarely has direct empirical data to examine effects of the policy. Cai and Xu [3] viewed that banks are more cautious about long-term loans. For enterprises, rollover risk creates a preference for long-term borrowing [1]. Thus, the debt maturity is a focus. This paper researches on the change in the maturity of corporate debt of polluted enterprises and takes property into consideration. The research finds that long-term loan of polluted enterprises is significantly dropped after the policy. Extensive research shows that after green credit policy, long-term loan of state-owned polluted enterprises is higher than private polluted enterprises. The result shows that under hash green credit environment, banks are more cautious about loans to enterprises. In terms of the maturity of corporate debt, polluted enterprises are subject to severe constraints. However, state-owned polluted enterprises face fewer restrictions due to credit discrimination. Generally, green credit policy has achieved some success.

Contributions: On the one hand, this paper makes up for the loss of quantitative research about green credit policy, providing direct empirical evidence. On the other hand, this paper makes both vertical comparison of general polluted enterprises and horizontal comparison between state-owned enterprises and private enterprises. The research perspective is more comprehensive.

The paper is organized as follows: The second part is institution background, theoretical analysis and research hypothesis; The third part is research design; The fourth part is empirical results and analysis; The fifth part is conclusion and inspiration.

138.2 Institutional Background, Theoretical Analysis and Research Hypothesis

Extensive economic development model has brought prominent drawbacks after decades of economic growth myth, especially the environmental problems. Pollution of Zijin Mining, Harbin Pharmaceutical Group, Ruihai companies has caused widespread social concern, and environmental issues has become a social focus. The Ministry of Environmental Protection has been committed to punish polluted enterprises, adopting a serious of administrative measures, including limitation on area approval, supervision on environmental cases and administrative penalties. These measures gained certain short-term effects. But in the long term, comprehensive effect is not prominent. Under this background, green credit policy opens a new perspective for government regulation and supervision. It requires strict enforcement of both Ministry of Environmental Protection and financial institutions to constrain polluted companies. Green credit policy proposed that compliance of environmental regulation should be a necessary term of credit approval, strictly limiting lending to polluted enterprises. For illegal enterprises, banks should stop, ease or even withdraw loans as punitive measures. This can help guide adjustment and optimization of industrial structure, and overcome drawbacks of short-term governance, being more sustainable.

Debt maturity is an important aspect of debt financing. Short-term debt financing allows creditors to acquire information about corporate operation in time [5] while long-term debt financing may lead to information asymmetry and default risk [12]. Above research indicates that banks are more cautious about long-term debts. Thus if enterprises obtain more long-term bank loan, it passes good signal to outside investors as banks trust them. Many scholars have researched the relationship between corporate environmental performance and debt maturity. Shu and Zhang [10] and Shen and Ma [9] both fond that better environmental information disclosure level has dominant positive impact on debt maturity. For measurement of corporate environmental performance, existing research usually divide environmental performance into many specific aspects such as pollutant emissions, corporate environmental system, environmental violation, environmental management system certification.etc. They mark each aspect and then give them different weight to get a comprehensive point. Higher point means better environmental performance. This measurement may be kind of objective and banks may not take the same judgment standards. But no matter what standards banks select finally, after the green credit policy, banks are supposed to be more careful to polluted enterprises in general as potential environmental violation increase the risk of inability to repay. Considering self-interest and social responsibility, banks will control long-term debts to polluted enterprises. Based on above analysis, this paper proposes the following hypothesis:

Hypothesis 1 (H1): After green credit policy, long-term bank loan of polluted enterprises is significantly dropped.

A high proportion of state-owned enterprises is a typical characteristic of China. Song et al. [11] indicated that in China enterprises with political connections indeed face fewer financing restrains than those that do not. Other developing countries also have this phenomenon. Charumilind et al. [4] and Mian and Khwaja [7] fond that in Thailand and Pakistan firms with connections to politicians have greater access to long-term debt than firms without such ties. Above research demonstrates that in developing countries, political connections, as intangible guarantee, help enterprises gain more advantage in debt financing. As for environmental regulation, does it have the same influence on both state-owned enterprises and private enterprises? Xu and Wan [14] pointed out that environmental regulation has worsen financing constraints of private enterprises while those of state-owned enterprises are improved. Wang [13] also supported a theory that links rent-seeking behavior to pollution. Green credit policy aims to limit all heavy-polluted enterprises regardless of corporate property. However, considering the realistic situation of our nation, banks will still give state-owned enterprises priority. The government background of state-owned enterprises can compensate for potential environmental risks to some extent. Also, state-owned enterprises, as enterprises controlled by government, should react to regulations issued by government more actively. Thus state-owned polluted enterprises are supposed to positively take measures to improve environment govern and reduce pollutant emission. That is to say, after the policy, state-owned polluted enterprises may have better environmental performance. Hence, banks will face less potential environmental risks when they provide loans to state-owned polluted enterprises. Compared to private polluted enterprises, banks are still more willing to provide credit to state-owned polluted enterprises. Based on above analysis, this paper proposes the following hypothesis:

Hypothesis 2 (H2): After green credit policy, long-term bank loans of state-owned polluted enterprises is higher than private polluted enterprises.

138.3 Research Design

138.3.1 Resource of Data and Sample Selection

Green credit policy was introduced since July 2007, therefore data from 2005–2007 and 2009–2011 of Shanghai Stock Exchange and Shenzhen Stock Exchange was selected as samples. Data from 2008 is excluded as financial crises in 2008 has great impacts on bank loans. All listed companies in A-share were included except financial institutions. After exclusion of missing data, 2712 observations were retained. Stage of 2005–2007 has 1226 observations while stage of 2009–2011 has 1486 observations. Extreme value was winsorized (1 %) in this paper. Financial data was downloaded from GTA database. Classification of polluted enterprises was accorded to "Industry Classification Management List for Environmental Inspection of Listed Companies" by Ministry of Environmental Protection, as well as business scope and main products from Wind database.

138.3.2 Measurement of Variables

Maturity of corporate debt. There are two popular measurement methods: balance sheet method and incremental method [2]. This paper chooses the former one. Considering data availability and the fact that in China most long-term loans are from long-term bank loans, this paper uses long-term loans to measure long-term bank loans. Debt maturity is measured as long-term loan divided by total debt.

Control variables. This paper uses size, leverage, roa, period and growth as control variables. Detailed variable definition and measurement is in Table 138.1 below.

Table 138.1 Variable definition and measurement

Variable type	Variable name	Measurement
Explained variable	Debt maturity	Long-term loan/total debt
Explanatory variable	Stage	Dummy variable, polluted enterprises = 1, otherwise = 0
	Property	Dummy variable, state-owned polluted enterprises = 1, otherwise = 0
Control variable	Size	Natural logarithm of total asset
	Leverage	Total debt/total asset
	Roa	Net profit/average total asset
	Period	Net value of fixed asset/total asset
	Growth	Change in main operating income/operating income last year
	Industry	Dummy variable

138.3.3 Model Design

Model (138.1) is designed to test Hypothesis 1. The main explanatory variable is stage, the explained variable is debt maturity. Coefficient a_1 is expected to be negative. Model (138.2) is used to test Hypothesis 2, the main explanatory variable is property, the explained variable is debt maturity. Coefficient a_1 is expected to be positive.

$$\begin{aligned}\text{Debt maturity} = {} & a_0 + a_1\text{Stage} + a_2\text{Size} + a_3\text{Leverage} + a_4\text{Roa} + a_5\text{Growth} \\ & + a_6\text{Period} + \text{IND} + \varepsilon, \qquad (138.1)\\ \text{Debt maturity} = {} & a_0 + a_1\text{Property} + a_2\text{Size} + a_3\text{Leverage} + a_4\text{Roa} + a_5\text{Growth} \\ & + a_6\text{Period} + \text{IND} + \varepsilon. \qquad (138.2)\end{aligned}$$

138.4 Empirical Results and Analysis

138.4.1 Descriptive Statistic Analysis

Results of descriptive statistics of Hypothesis 1 are shown in Table 138.2. The results show that average debt maturity 0.1450 and median debt maturity 0.0784 of stage 0 are both higher than average value 0.1278 and median value 0.0508 of stage1. It means that debt maturity of polluted enterprises is lower after enforcement of green credit policy.

Results of descriptive statistics of Hypothesis 2 are shown in Table 138.3. The results show that after green credit policy, average debt maturity 0.1732 and median debt maturity 0.1178 of state-owned polluted enterprises are both higher than aver-

Table 138.2 Descriptive statistics of H1

Variable	Stage = 0 (2005–2007)			Stage = 1 (2009–2011)		
	Average	Median	Deviation	Average	Median	Deviation
Debt maturity	0.145	0.0784	0.1708	0.1278	0.0508	0.1678
Size	21.4854	21.3973	1.1542	21.9017	21.6656	1.3492
Leverage	0.5354	0.5332	0.2247	0.4804	0.4838	0.2566
Roa	0.0336	0.0346	0.0813	0.0505	0.0432	0.081
Growth	0.2143	0.1681	0.3814	0.2156	0.1777	0.33
Period	0.3967	0.39	0.1687	0.3235	0.3034	0.1752

Table 138.3 Descriptive statistics of H2

Variable	Private polluted enterprises			State-owned polluted enterprises		
	Average	Median	Deviation	Average	Median	Deviation
Debt maturity	0.0684	0	0.1159	0.1732	0.1178	0.1863
Size	21.29	21.171	0.9685	22.3775	22.2039	1.4277
Leverage	0.3915	0.3711	0.2765	0.5464	0.5529	0.2112
Roa	0.067	0.0659	0.0845	0.0393	0.0302	0.0741
Growth	0.2256	0.184	0.3105	0.2054	0.174	0.3166
Period	0.2547	0.2265	0.1561	0.376	0.3697	0.171

age value 0.0684 and median value 0 of private polluted enterprises. It means that debt maturity of state-owned polluted enterprises is higher than private polluted enterprises after enforcement of green credit policy.

138.4.2 Regression Results Analysis

Table 138.4 shows mixed regression test results of model (138.1) and model (138.2). From the first column of regression results, the coefficient of Stage is significantly negative. It means that comparing to stage before green credit policy, debt maturity of polluted enterprises is dramatically dropped after enforcement of the policy. Banks has controlled the long-term loan to polluted enterprises in general. Hypothesis 1 is supported. From regression results of the second columns, the regression coefficient of Property is significantly positive. This demonstrates that after green credit policy, compared to private polluted enterprises, debt maturity of state-owned polluted enterprises is higher. Banks give state-owned polluted enterprises priority. Private polluted enterprises suffer more limitations. Hypothesis 2 is supported.

Table 138.4 Regression results

	(1) Debt maturity	(2) Debt maturity
Stage	−0.015	–
	(−2.74)**	–
Property	–	0.02
	–	(2.55)**
Size	0.041	0.038
	(16.04)***	(10.70)***
Leverage	0.062	0.065
	(4.95)***	(3.83)***
Roa	0.108	0.058
	(2.84)***	−1.13
Growth	0.009	0
	−1.12	(−0.00)
Period	0.201	0.173
	(10.37)***	(6.13)***
Industry	YES	YES
N	2712	1486
adj. R2	0.374	0.369

Note (1) reported values are T statistics; (2) *, **, *** representing 10 %, 5 %, 1 % significant levels

In addition, this paper also takes robustness test. Another measurement of debt maturity is used. Debt maturity = long-term loan/(short-term loan + long-term loan + long-term debt due within one year). The results remain unchanged. The coefficient of Stage is significantly negative while the coefficient of Property is significantly positive. It indicates that regression results are reliable.

138.4.3 Extensive Analysis

In balance sheet, long-term debts include long-term loan, corporate bonds payable, long-term payable, grants and subsidies received. Through above analysis of Hypothesis 1, this paper finds that long-term loans of polluted enterprises are decreased. Hence will polluted enterprises transfer to rest long-term debts as replacement? This paper does further research. Other Debt1 = (long-term debt − long-term loan)/total debt, Other Debt2 = (long-term debt − long-term loan)/(total debt − long-term loan). Model (138.3) and model (138.4) are used to examine the extensive hypothesis. Regression results in column (3) and column (4) indicate that coefficients of Stage are both significantly positive. Thus due to constrains on long-term loan, polluted enterprises transfer to other long-term debt. Other long-term debt of polluted enterprises arises after green credit policy (Table 138.5).

Table 138.5 Descriptive statistics of H2

	(3) Other debt1	(4) Other debt2
Stage	0.036	0.041
	(12.16)***	(11.84)***
Size	0.009	0.015
	(6.00)***	(8.39)***
Leverage	−0.017	−0.012
	(−2.20)**	(−1.51)
Roa	−0.01	−0.015
	(−0.46)	(−0.67)
Growth	−0.002	−0.004
	(−0.49)	(−0.74)
Period	−0.022	−0.016
	(−1.90)*	(−1.24)
Industry	YES	YES
N	2712	2712
adj. R2	0.118	0.145

$$\begin{aligned}\text{Other Debt1} &= a_0 + a_1\text{Stage} + a_2\text{Size} + a_3\text{Leverage} + a_4\text{Roa} + a_5\text{Growth} \\ &\quad + a_6\text{Period} + \text{IND} + \varepsilon, \qquad (138.3)\\ \text{Other Debt2} &= a_0 + a_1\text{Stage} + a_2\text{Size} + a_3\text{Leverage} + a_4\text{Roa} + a_5\text{Growth} \\ &\quad + a_6\text{Period} + \text{IND} + \varepsilon. \qquad (138.4)\end{aligned}$$

138.5 Conclusion and Inspirations

This paper takes a direct empirical data test on effects of green credit policy. It finds that under more strict environment regulation, banks constrain long-term loans to polluted enterprises generally in case of potential environmental violation risks. Long-term loan of polluted enterprises is significantly dropped after the policy. Results of this study illustrate that green credit policy has gained some success. However, when taking property factor into consideration, this paper views that compared to private polluted enterprises, state-owned polluted enterprises suffer less impacts. In terms of the maturity of corporate debt, private polluted enterprises are subject to more severe constraints. Credit discrimination still exits.

Inspirations: Government regulation of capital market is effective. For social responsibility, the solely administrative means are not enough and long-lasting. Green credit policy is an innovation which try to solve social environmental problems through financing methods. Combination of administrative means and financial methods provide a more effective way to solve social problems. In the future, government can continue to integrate financial methods to strengthen supervision. Furthermore, green credit policy needs more detailed standards. Existing green credit policy only provides a general framework. More quantitative and operational environmental information disclosure regulation and environmental pollution rating system should be introduced [6]. With more specific rules, banks can comply with green credit policy better while polluted enterprises can be guided to improve environmental performance.

Acknowledgments Fund project: General project of National Natural Science Foundation of China (71302132); General Project of Social Science Planning of Sichuan Province(SC15B041).

References

1. Badoer DC, James CM (2016) The determinants of long-term corporate debt issuances. J Financ 71:457–492
2. Barclay MJ, Smith CW (1995) The maturity structure of corporate debt. J Financ 50(2):609–631
3. Cai HJ, Xu H (2011) Progress of marketization, environmental information disclosure and green loan. Collect Essays Financ Econ 5:011
4. Charumilind C, Kali R, Wiwattanakantang Y (2006) Connected lending: Thailand before the financial crisis. J Bus 79(1):181–218
5. Diamond DW (1991) Debt maturity structure and liquidity risk. The Quarterly Journal of Economics pp 709–737
6. Li P, Shen Y (2011) Social norm, capital market and environmental governance: empirical evidence from the view of institutional investors. World Econ 6:126–146 (in Chinese)
7. Mian AR, Khwaja AI (2005) Do lenders favor politically connected firms? Rent provision in an emerging financial market. Rent Provis Emerg Financ Market 4:1371–1411
8. Niamh O'Sullivan BO (2015) The structuration of issue-based fields: social accountability, social movements and the equator principles issue-based field. Account Organ Soc 43:33–55
9. Shen H, Ma Z (2012) Develop economy or protect environment–evidence from debt financing of heavy-polluted listed companies. International annual conference of environmental accounting committee in ASC and the 1st Chinese CSEAR
10. Shu L, Zhang J (2014) Impact of environmental information disclosure to bank credit maturity. Account Organ Soc 6:45–51
11. Song M, Ai H, Li X (2015) Political connections, financing constraints, and the optimization of innovation efficiency among China's private enterprises. Technol Forecast Soc Change 92:290–299
12. Stiglitz JE, Weiss A (1981) Credit rationing in markets with imperfect information. Am Econ Rev 71(3):393–410
13. Wang Y (2015) Politically connected polluters under smog. Bus Polit 17(1):97–123
14. Xu S, Wan H (2011) Environmental regulation, government support and financing constraints of heavy-polluted industry. Stat Inf Forum 9:77–83

Erratum to: Proceedings of the Tenth International Conference on Management Science and Engineering Management

Jiuping Xu, Asaf Hajiyev, Stefan Nickel and Mitsuo Gen

Erratum to:
J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4

The book was inadvertently published without including the editor's name and affiliation in the front matter. The erratum book has been updated with the changes.

The updated original online version for this book frontmatter can be found at 10.1007/978-981-10-1837-4

J. Xu (✉)
Business School, Sichuan University, Chengdu, Sichuan, China
e-mail: xujiuping@scu.edu.cn

A. Hajiyev
Azerbaijan National Academy of Science, Baku, Azerbaijan
e-mail: asaf@baku-az.net

S. Nickel
Karlsruhe Institute of Technology, Karlsruhe, Baden-Württemberg, Germany
e-mail: stefan.nickel@kit.edu

M. Gen
Tokyo University of Science, Fuzzy Logic Systems Institute Tokyo University of Science, Tokyo, Japan
e-mail: gen@flsi.or.jp

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4_139

Author Index

J. Xu et al. (eds.), *Proceedings of the Tenth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 502, DOI 10.1007/978-981-10-1837-4

U

V

W

X

Y