Advances in Intelligent Systems and Computing 280

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Virgílio António Cruz-Machado
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Stefan Nickel *Editors*

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

Focused on Intelligent System and Management Science

Springer

Advances in Intelligent Systems and Computing

Volume 280

Series editor

Janusz Kacprzyk, Warsaw, Poland

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Editors

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ISSN 2194-5357 ISSN 2194-5365 (electronic)
ISBN 978-3-642-55181-9 ISBN 978-3-642-55182-6 (eBook)
DOI 10.1007/978-3-642-55182-6
Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2014937306

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Welcome to the *Proceedings of the Eighth International Conference on Management Science and Engineering Management* (ICMSEM2014) held from July 25 to 27, 2014 at Universidade Nova de Lisboa, Lisbon, Portugal.

The International Conference on Management Science and Engineering Management is the 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 as well as to provide a forum to present current research results in the forms of technical sessions and round table discussions during the conference period in a relaxed and enjoyable atmosphere. This year, 1,337 papers from 37 countries were received and 138 papers from 14 countries were accepted for a presentation or poster display at the conference after a rigorous review. These papers are from countries including Spain, Australia, Germany, France, Canada, Pakistan, China, USA, Japan, Portugal, Iran, The Netherlands, Korea, and Azerbaijan. They are classified into eight parts in the proceedings, which are Intelligent Systems, Decision Making Systems, Manufacturing, Supply Chain Management, Computing Methodology, Project Management, Industrial Engineering, and Information Technology. The key issues of the eighth ICMSEM cover various areas in MSEM, such as Decision Making Methods, Computational Mathematics, Information Systems, Logistics and Supply Chain Management, Relationship Management, Scheduling and Control, Data Warehousing and Data Mining, Electronic Commerce, Neural Networks, Stochastic models and Simulation, Heuristics Algorithms, and Risk Control. In order to further encourage the state-of-the-art research in the field of Management Science and Engineering Management, the ISMSEM Advancement Prize for MSEM will be awarded at the conference to these researchers.

A total of 138 papers were accepted and they were divided into two proceedings with 69 papers in each proceeding. To find out the research topics among the accepted papers, the NodeXL was applied. To begin with, keywords from 69 papers were excerpted as follows: Genetic algorithms, Simulation, Decision Making Systems, Innovation, Human resource management, Supply Chain Management, Hazards, Risks, Occupational accident, Occupational diseases, Exogenous influence, Scale invariant, Network architecture, Computer simulation, Neural networks, Hardware product, Defects, Functional assessment, Genetic algorithms, Medical problems, Game theory, Mixed payment, Statistical process control, Autocorrelation, Chart, Mathematical programming, Production-distribution problem, Fuzzy random variable, Multi-attribute auction, Reverse auction, Data envelopment analysis, Television applications-Industry, Evaluation, Empirical analysis, National high-tech zones, VIKOR method, Prediction, Transfer learning, Empowerment of personnel, Fuzzy sets, Fuzzy Analytic Hierarchy Process (FAHP), Regional innovation system, Innovation, Principal component analysis, Transactive memory system, Multiactivity task, Feedback control, Simulation, Group learning, Construction safety investment, Regulation, Evolution, Stable strategy, Lurker, Computing, SMEs, ARIMA, Forecasting, Mathematical models, Traffic control, Decision trees, Infrastructure, Integration, Decision group, Complex network, Superiority index, Fuzzy logic, SIR, GEMS, Strategic transformation, Mechanisms, Transformation process, Financial development, Regression analysis, AHP, Agent based modeling, Agribusiness, Dynamic analysis, Competitive advantage, IT strategy, Business strategy, Organizational aspects, Environmental management, life support system, Big data, Enterprise resource management, Statistics, Corporate governance, Organizational effectiveness, Economic analysis, Financial risk, Purchasing, Lean, Trade credit, Uncertainty analysis, Multiobjective optimization, Inventory control, Air transportation, Profit allocation, Preventive maintenance, Knowledge management, Fractals, Green supply chain, Performance, Talent management, PSO, Organization, Replacement policy, Quality improvement.

The significance of the keywords does not lie only in its frequency or ratio; the connection between the keywords is also very important in our study of how these papers revolve around the theme of Management Science (MS). The field of MS provides a set of concepts and metrics to systematically study the relationships between the keywords. The methods of information visualization have also become valuable in helping us to discover patterns, trends, clusters, and outliers, even in complex social networks. In the preface, the open source software tool NodeXL was designed especially to facilitate learning the concepts and methods of MS as a key component.

Using the NodeXL, all of the 487 keywords involved in the 69 papers were analyzed. To begin with, the preliminary processing was executed on all the keywords. Except for a unified expression of words, all the keywords with the same meaning and words including the meaning of similar keywords have been unitized. For example, “decision making systems,” “decision making,” and “decision support systems” have finally been unified to “decision making systems.” Through the preliminary processing, the keywords have been reduced to 443, making it possible to constitute the network efficiently.

These processed keywords represented as the vertexes in NodeXL will be visualized in a network diagram. In the network diagram, the vertexes’ sizes have been set to depend on the number of other vertexes associated with it. The more the vertex connects with other vertexes, the higher centrality it would be, which reflects the keyword’s important status in the field of MS. In other words, this keyword is likely to represent an important issue in MS. At the same time, the

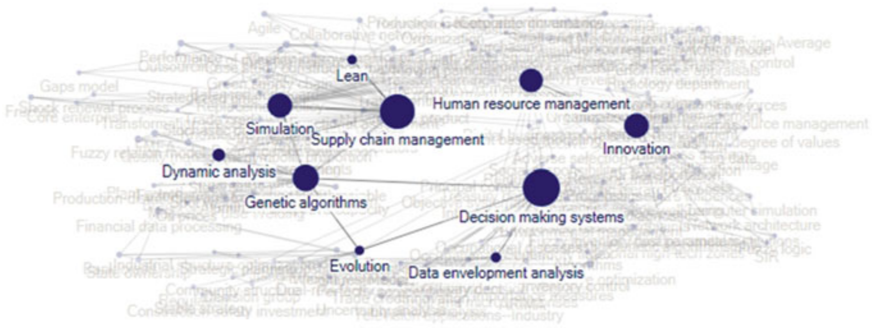

FIg. 1 Research topics in MS for the Eighth ICMSEM

vertexes' shapes have been set to depend on their betweenness and closeness centrality. When the degree of a vertex's betweenness and closeness centrality is beyond a certain value, the shape of this vertex would be square. The goal is to find out some key concepts in the field of MS. These key concepts are likely to be the important nodes that connect with other research topics.

Through the above steps, a network constituted by the keywords representing the relationship between them is demonstrated in Fig. 1. It shows that decision making systems, supply chain management, genetic algorithms, simulation, innovation, and human resource management are key concepts which are the important nodes connected with other research topics. In other words, they are key issues about MS in the accepted 69 papers in this volume.

In this volume, the proceedings concentrate on Intelligent Systems, Decision Making Systems, Manufacturing, and Supply Chain Management. To begin with, Intelligent Systems are the basic MSEM tools, as they provide a foundation for the discussion of practical management problems. Genetic algorithms and simulation are their key concepts. In this part, Safari et al. propose a new model based on Fuzzy AHP and VIKOR methods to rank bank branches in the field of employee empowerment issues. Matos et al. present a methodology to be applied when the data exhibit autocorrelation and, in parallel, to illustrate the strong capabilities that simulation can act as a key tool to determine the best control chart, taking into account the process's dynamic behavior. Zheng et al. explore the assessment on hardware design defects. Through the fuzzy neural network-based genetic algorithm, the assessment model had excellent capabilities with a high accuracy and good training speed, thus providing an effective tool for assessing design defects of the hardware product. Ferreira et al. demonstrate that the integration of harmonized classifications allows comparisons of data and statistics, at national and European levels, which were impossible before. The research in this section shows an excellent combination of computer-based techniques and practical guidance.

Part II is focused on Decision Making Systems. Decision Making Systems emphasize on computer-based information systems that support knowledge management, decision making, and management reporting and that assist managers in making decisions in highly uncertain and complex environments. In this part, Alberto et al. investigate complex logistical and operational systems. Decision Trees (DT) and Binary Decision Diagrams (BDD) are used to find the best solution to the main problem. Applying the aforementioned methodology provides the company with a powerful method in the DM process and also an approach to increase the reliability. Asaf et al. introduce a mathematical model of moving particles and apply it to the traffic area. Chen et al. examine the portfolio approach in terms of multiple delivery method integration, technology, and centralized control system, and evaluate the replicability of the new model. Practices and lessons learned from the case are then presented and summarized so that they can be applied to the township sewage treatment facility development. Miyamoto explores a relationship between each of the five forces and IT strategies, as well as the relationship between those and business strategies among Japanese SMEs.

Manufacturing is the use of machines, tools, and labor to produce goods that meet a customer's expectations or specifications, and innovation and human resource management are their key concepts. Lucas and Tenera propose a methodology to deal with the variability inherent to systems, resorting to statistical inference methods: hypotheses testing. These methods are a vigorous tool on the analysis of data collected from the system. Cabrita et al. analyze to which extent technological and organizational innovation concepts are diffused in Portuguese manufacturing companies. They also analyze how the use of technological innovation concepts which are interrelated to the use of organizational innovation concepts based on previous studies developed in Europe and from data collected from the European Manufacturing Survey (EMS). Zhou and Wang investigate the impulse responses of different macroeconomic variables and financial variables to the oil price shock as well as the effect of interest rate changes and the use of Granger Causality Test to evaluate the correlation between oil prices, stock markets, and gold prices. Zhang and Liu apply DEA to analyze the Jiangsu province's productivity of shipbuilding both in the aspects of technology and scale. The excess capacity caused by over-input of personnel, material, and poor management led to the inadequate productivity of shipbuilding in Jiangsu.

Part IV focuses on Supply Chain Management (SCM). It is an interconnected businesses network which is involved in the ultimate provision of product and service packages required by end customers. In this part, Duarte and Machado explore how to reach benefits on supply chain performance, considering the lean and green performance measures through the traditional BSC perspectives. It is possible to recognize that lean and green initiatives influence the linkages between performance measures. These linkages in the scorecard are an example of how to evaluate the organization's supply chain. Chantarachalee et al. provide perspectives on how to design lean supply chains. It describes a real case study related to construction materials supply chain. The case study considers a supply chain setting where the dealers have dominant bargaining power over the manufacturer. Wang et al. investigate the problem of profit allocation under bilateral asymmetric information environment and analyze the relationship between the expected information rents and the realized supply chain profit. By using the idea of the

R-S-K bargaining solution, the realized total chain's profits are allocated reasonably. Hanif et al. analyze the previous studies, and take qualitative input and feedback from senior HR experts of the telecom sector to scroll the importance of integration of diversity management and talent management practices.

The four parts containing 69 papers were hot research topics in MS. In addition to the high-quality proceedings, the conference also provides a suitable environment for discussions and exchange of research ideas among participants during its well-organized conference. Although we present our research results in technical sessions and participate in round table discussions during the conference period, we will also have extra and fruitful occasions to exchange research ideas with colleagues in this relaxed and enjoyable atmosphere of sightseeing.

We want to take this opportunity to thank all the participants who have worked hard to make this conference a success. We appreciate the help from Universidade Nova de Lisboa and Sichuan University in conference organization. We also appreciate Springer-Verlag London for the wonderful publication of the proceedings. We are also grateful to Rector António Manuel Bensabat Rendas for being the General Chair and Prof. Dr. Fernando Santana for being the Local Arrangement Committee Chair. In addition, we appreciate the great support from all members of the Organizing Committee, Local Arrangement Committee, and Program Committee as well as all participants who have worked hard to make this conference a success. We also want to appreciate all the authors for their excellent papers in this conference. Due to these excellent papers, the ISMSEM Advancement Prize for MSEM will be awarded again at the conference for the papers that describe a practical application of Management Science and Engineering Management. The Ninth International Conference on Management Science and Engineering Management will be hosted by Karlsruhe Service Research Institute (KSRI), Karlsruhe Institute of Technology, Germany in July, 2015. Prof. Dr. Stefan Nickel will be the Organizing Committee Chair for 2015 ICMSEM. We sincerely hope that you can submit your new findings on MSEM and share your ideas in Germany.

Lisbon, Portugal, 20 May 2014

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Organization

ICMSEM 2014 was organized by International Society of Management Science and Engineering Management, Sichuan University (Chengdu, China), Universidade Nova de Lisboa (Caparica Portugal). It was held in cooperation with Advances in Intelligent Systems and Computing (AISC) of Springer.

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Contents

Part I
Intelligent Systems

Chapter 1
Average Run Length Performance Approach to Determine the Best Control Chart When Process Data is Autocorrelated

Ana Sofia Matos, Rogério Puga-Leal and José Gomes Requeijo

Abstract Most conventional Statistical Process Control techniques have been developed under the assumption of the independence of observations. However, due to advances in data sensing and capturing technologies, larger volumes of data are routinely being collected from individual units in manufacturing industries and therefore data autocorrelation phenomena is more likely to occur. Following this changes in manufacturing industries, many researchers have focused on the development of appropriate SPC techniques for autocorrelated data. This paper presents a methodology to be applied when the data exhibit autocorrelation and, in parallel, to evidence the strong capabilities that simulation can provide as a key tool to determine the best control chart to be used, taking into account the process's dynamic behavior. To illustrate the proposed methodology and the important role of simulation, a numerical example with data collected from a pulp and paper industrial process is provided. A set of control charts based on the exponentially weighted moving average (EWMA) statistic was studied and the in and out-of-control average run length was chosen as performance criteria.The proposed methodology constitutes a useful tool for selecting the best control chart, taking into account the autocorrelated structure of the collected data.

Keywords Statistical process control (SPC) · Autocorrelated data · Average run length (ARL) · Exponentially weighted moving average (EWMA) · EWMAST chart · MCEWMA chart

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_1,

1.1 Introduction

Traditional statistical process control assumes that consecutive observations from a process are independent. Nowadays, in industrial processes, autocorrelation has been recognized as a natural phenomenon, more likely to be present when:

- Parameters, such as temperature and pressure, are subject to small variations considering the rate at which they are measured;
- The presence of tanks and reactors inducts inertial process elements;
- Data is sequentially sampled in time and with a sampling rate that can be very high, due to high-performance measurement devices.

Chemical and pharmaceutical industries can be pointed as examples of processes where the existence of autocorrelation in data is extremely likely. Only in recent years has autocorrelation become an important issue in statistical process applications, particularly in the industrial field and, due to this fact, a large number of researchers has focused and contributed to this field of knowledge.

Data independency assumption violation is incurred when autocorrelation is present between two consecutive measurements that may cause severe deterioration of standard control chart performance, usually measured in terms of run length (RL), i.e. the number of observations required to obtain an observation outside of the control limits [6, 7].

Several authors have studied and discussed the negative effects of traditional control charts applied to processes with autocorrelated observations [1, 4, 6]. In these cases, there is a significant increase in the number of false alarms, or a considerable loss of control chart sensitivity, caused by incorrect estimation of process parameters. As a consequence, these two situations can produce, respectively: pointless searches for special causes, maybe with costly discontinuity in the production rates; and a loss of sensitivity that may undermine product reputation and discredit this powerful tool.

In order to overcome these limitations, two main approaches have emerged. The first approach uses traditional control charts for independent and identically distributed data (iid) but with suitably modified control limits to take into consideration the autocorrelation structure [4, 9]. The second approach uses time series models to fit to the observations and apply traditional control charts to the residuals from this model [1, 3].

The main goal of this article is to present a methodology that points out the main issues to be considered in both phases of control chart implementation (phase I and II) and to provide a set of guidelines when simulation is used for optimal Control Chart selection with autocorrelated data. A stationary first-order autoregressive AR(1) process was considered in the study with individual observations. As a performance criterion, it was used the average run length (ARL) and their corresponding standard deviation of the run length (SDRL). In this study, a set of widely accepted control charts applicable for monitoring the mean of autocorrelated processes were selected, namely: the residual-based chart or the special control chart (SCC) of Alwan [1] (in both phase I and II), the Exponentially Weighted Moving

Average (EWMA) control chart for residuals [3], the EWMAST chart (EWMA for Stationary process) developed by Zang [9] and the MCEWMA chart (Moving-Centerline EWMA), with variable limits proposed by Montgomery and Mastrangelo [5]. Detailed simulation results are provided and suggestions are made.

1.2 Theoretical Background

1. EWMAST Chart

Zhang [9] proposes the EWMAST chart as being an extension of the traditional EWMA chart designed to monitor a stationary process. This chart uses the autocorrelation function to modify the control limits of the EWMA chart. The EWMA chart is defined by:

$$E_t = (1 - \lambda)E_{t-1} + \lambda X_t, \tag{1.1}$$

where X_t corresponds to data under control at a time t, $E_0 = \mu$ and the parameter $\lambda(0 < \lambda < 1)$ is a constant. The approximate variance, according to Zhang [9] is given by:

$$\sigma^2_{\text{EWMAST}} \approx \sigma^2 \left(\frac{\lambda}{2-\lambda}\right)\left(1 + \sum_{k=1}^{M} \rho_k (1-\lambda)^k (1 - (1-\lambda)^{2(M-k)})\right), \tag{1.2}$$

where $\rho_x(k)$ is the process autocorrelation at lag k and M is an integral ≥ 25. The control limits of this chart are given by:

$$\begin{cases} LSC_{\text{EWMAST}} = E_0 + L^{\text{EWMAST}} \hat{\sigma}_{\text{EWMAST}} \\ LC_{\text{EWMAST}} = E_0 \\ LSC_{\text{EWMAST}} = E_0 - L^{\text{EWMAST}} \hat{\sigma}_{\text{EWMAST}}, \end{cases}$$

where L is usually equals to 2 or 3.

Note that when the data process are independently and identically distributed, or white noise, $\rho_x(k) = 0$ when $k \neq 0$. In this case, the EWMAST chart and the traditional EWMA are de same.

Zhang [9] shows that for stationary AR(1) processes the EWMAST chart performs better than the EWMA residual chart and, that's an obvious advance for using EWMAST chart is that is no need to build a time series model for stationary process data.

2. MCEWMA Chart

Montgomery and Mastrangelo [5] developed a new chart that brings together all the information on the MM chart, also developed by these authors, in a single one called MCEWMA chart. This chart allows, simultaneously, analyzes the evolution of the process behavior and detect special causes of variation.

Defining the variable E_t by Eq. (1.1) and considering that $\hat{X}_t = E_{t-1}$, the residual e_t, at time t is given by: $e_t = X_t - \hat{X}_t = X_t - E_{t-1}$. The control limits and centerline of the MCEWMA chart vary over time and, are defined at time t, by:

$$\begin{cases} LSC_t = E_{t-1} + 3\sigma_{ep} \\ LC_t = E_{t-1} \\ LSC_t = E_{t-1} - 3\sigma_{ep}, \end{cases}$$

where the standard deviation of forecast errors, σ_{ep}, can be estimated by any of the following equations:

$$\hat{\sigma}_{ep} = \frac{1}{N}\sum_{t=1}^{N} e_t^2,\ \ (\hat{\sigma}_{ep})_t \cong 1.25\,\text{DAM}_t,\ \ (\hat{\sigma}_{ep})_t = (1-\alpha)(\hat{\sigma}_{ep})_{t-1} + \alpha|e_t|,$$

with DAM_t corresponding to the mean absolute deviation, given by:

$$\text{DAM}_t = (1-\alpha)\text{DAM}_{t-1} + \alpha|e_t|, \tag{1.3}$$

and $0 < \alpha \leq 1$.

The MCEWMA chart presents a poor sensitivity in detecting small or moderate changes in the process mean. Taking into account this limitation, Montgomery and Mastrangelo [5] proposed the use of "tracking signal", which together with the MCEWMA chart help increase its sensitivity in detecting trends. The smoothed-error tracking signal, $Ts(t)$, can be obtained by: $Ts(t) = \left|\frac{Q_t}{\text{DAM}_t}\right|$, where $Q_t = \alpha e_t + (1-\alpha)Q_{t-1}$ and DAM_t defined by (1.3), with $0.05 \leq \alpha \leq 0.15$ as a smoothing constant. When the $Ts(t)$ exceeds a constant Ks, typically with values between 0.2 and 0.5, means that the forecast error is biased, indicating a change in the underlying process.

3. EWMA Chart with Residuals

The traditional EWMA chart may also be built using residuals, by using residual values instead of the data collected from the process. The use of these charts significantly increases detection of minor to moderate changes of the expected residual value and its variance σ_e^2 and, consequently changes in process parameters. The statistic used in the EWMA of residuals chart, to monitor the process mean at time t is given by: $\text{EWMA}_t = (1-\lambda)\text{EWMA}_{t-1} + \lambda e_t$ with $\text{EWMA}_0 = 0$ and $\theta = 1 - \lambda$.

The control limits are simply given by: $\pm L^{\text{EWMA}_{res}}\sigma_{\text{EWMA}_{res}}$, where the variance of residual EWMA statistics is:

$$\sigma^2_{\text{EWMA}_{res}} \approx \sigma_e^2\left(\frac{\lambda}{2-\lambda}\right). \tag{1.4}$$

1.3 Methodology

In Fig. 1.1 the proposed methodology is presented, providing a basis for control chart implementation guidance when the assumption of data independence is violated. The methodology, in general, does not differ significantly from the approach that is generally used when the data are independent, but there are important aspects to

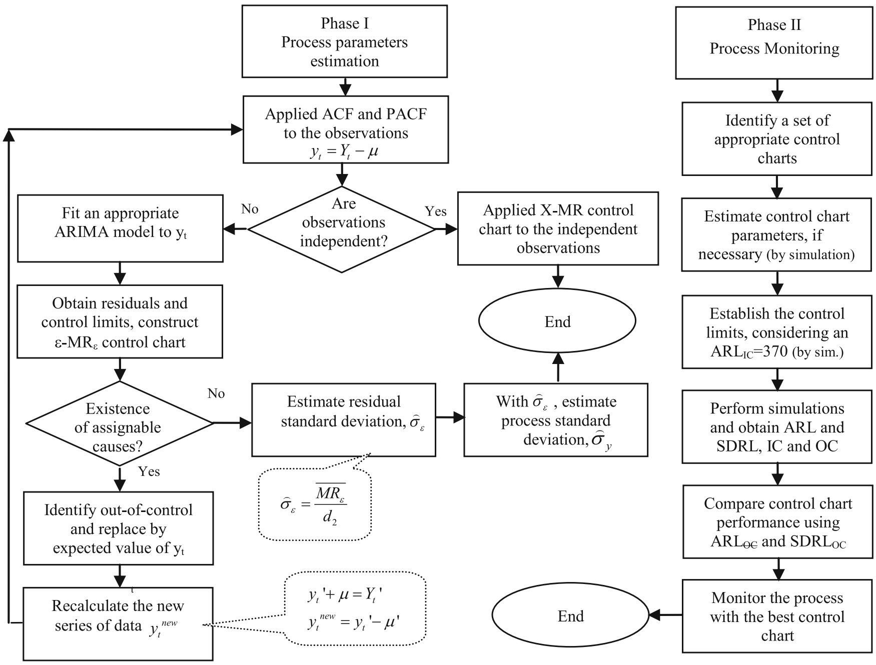

Fig. 1.1 Methodology for phase I and II

consider, including the treatment of special variation causes that may arise in Phase I, the correct selection of a set of control charts and the important role that simulation can play in identifying the best control chart to be used in Phase II.

1. Phase I:Process Parameter Estimation

The evaluation of process stability and subsequent estimation of its parameters are the main objectives underlying the Phase I. However, it is necessary to verify that the assumptions underlying its implementation are satisfied (independence and normality of data). The verification of the first assumption can be ensured by the interpretation of the sample ACF (autocorrelation function) and the sample PACF (partial autocorrelation function) of the residuals. If there is significant autocorrelation in the data, it is implicit that the second assumption is valid, since the residuals obtained from a well adjusted ARIMA model should be normally distributed with zero mean and constant variance. After fitting an appropriate time series model, a residual-based control chart should be used. The existence of assignable causes indicates the presence of special causes of variation and requires a different treatment that does not pass by mere identification and elimination of those special causes, as if data were uncorrelated. Since autocorrelated data is characterized by having time-oriented observations, when an assignable cause is detected in phase I, the value y_t, in that instance, should be replaced by their expected value at time t.

The calculation of expected values can be done by applying an outlier's detection model [2]. After achieving process stability, the final step consists on parameter estimation: residual standard deviation, process mean and process standard deviation.
2. Phase II: Process Monitoring

After evaluating process stability, process monitoring will take place. The first step comprises the identification of a set of candidate control charts. This selection may include control charts with modified control limits (1st approach) and/or control charts with residuals obtained from a time series model (2nd approach). To help with the selection, some guidelines can be found in Montomery [6], Zhang [9], and Sheu and Lu [8]. The choice of a suitable control chart depends, in a large way, on the type of shifts (δ) in mean and/or standard deviation or changes in ARIMA's model parameters that are to be detected. The last step to be fulfilled in phase II comprises a comparison of the control chart's performance through collecting ARL out-of-control (ARL_{OC}) and correspondent SDRL, when the process is subject to shifts/changes in parameters (mean, standard deviation or ARIMA model parameters). Once more, simulation reveals to be a valuable and indispensable tool in achieving this milestone, i.e., defining the optimum control chart to be used in monitoring phase.

1.4 Case Study

The case study refers to a pulp and paper process, where individual paper pulp viscosity measurements were collected from the bottom of a 100 m high digester. This type of process is characterized as being continuous and highly dynamic. For phase I, a sample of 300 viscosity measurements were obtained, collected every four hours and analyzed in the laboratory. Moreover, this sample represents a period of 50 production days, which is also representative in what respects to process dynamic behavior. For phase II, a sample size of 200 viscosity measurements were collected at the same conditions, corresponding to a period of 33 production days.
1. General

According to phase I showed in Fig. 1.1, underlying control chart assumption verification should be compulsory, especially when data is provided from a continuous and high dynamic process. Nowadays, several commonly available software packages (Statistica®, Matlab®, Minitab®) allow a fairly expeditiously assumption check. The present study adopts the use of Statistica® software package in order to obtain the sample ACF and sample PACF, with the 300 viscosity measurements, both represented in Fig. 1.2.

Graphic interpretation clearly shows that data follows an autoregressive first order model, AR(1), evidenced by slow ACF peak decline and existence of only one significant PACF peak.

The time series model that better adjusts to data was obtained with an autoregressive parameter ϕ equal to 0.561 (standard error of ϕ equal to 0.0528). Process mean obtained from viscosity measurements was $\mu_y = 1076.45$, with $\sigma_y = 47.923$ (process standard deviation) and $\sigma_s = 39.677$ (residual standard deviation).

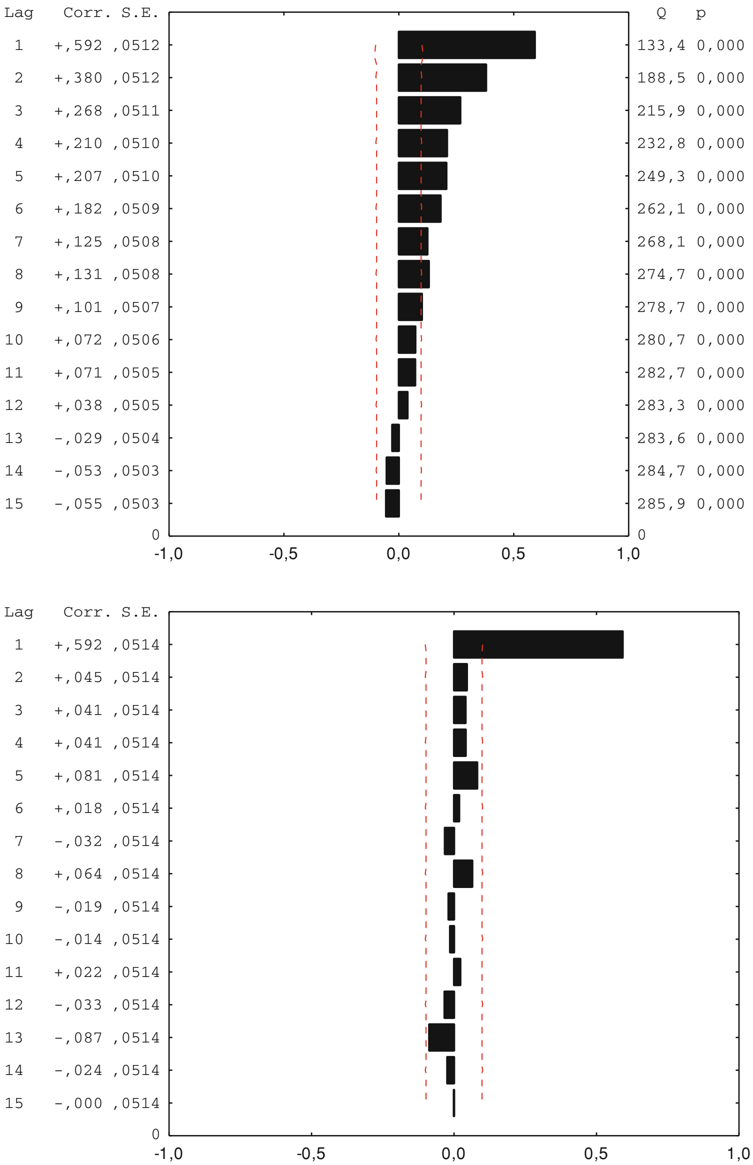

Fig. 1.2 Sample partial autocorrelation function (PACF) for viscosity

Since the first-order autor regressive residuals, ε_t, are assumed to be independent and identically distributed (iid) with mean zero and σ_s constant, the first residual control chart can be established, considering an ARLIC $= 370$. For this ARL_{IC} the control limits are given by $\pm 3 \times \sigma_s$, taking a numerical value of ± 119.0. For the residual moving range (MR) chart the upper control limit is given by $3 \times MR_s/1.128$, with centerline equal to MR_s. The numerical values for upper control limit and centerline are 146.2 and 44.7, respectively. The lower control limit is equal to zero.

The residual control charts, $\varepsilon_t - MR_s$, were constructed and the existences of five possible assignable causes were identified (values outside the control limits). According to the methodology in Fig. 1.1, those possible assignable causes cannot simply be eliminated, requiring their replacement with the corresponding expected values. The iterative outlier's detection model was applied and the corresponding expected value for each outlier was determined and replaced on the original data set. A new data set, ytnew with the same length, is obtained as well as new estimates for process viscosity mean ($\mu_y^{\text{new}} = 1{,}074.0$) and corresponding standard deviation ($\sigma_y^{\text{new}} = 44.9$). The new adjusted time series model is given by:

$$y_t^{\text{new}} = 0.579 y_{t-1}^{\text{new}} + \varepsilon_t, \tag{1.5}$$

with standard error of autoregressive parameter, σ_s^{new}, equal to 0.0512 and residual standard deviation, σ_y^{new}, equal to 36.0. Comparing the new results with the previous ones, there is a slight increase in the autoregressive parameter (with decrease in standard error), followed by an adjustment in the process mean, reducing both the process and residual standard deviations, as expected. Based on the Eq. (1.5) model and in its parameters, new control limits were determined for both control charts: residuals and moving ranges. The numerical values obtained were ± 108.0 for residual control chart, 132.7 and 40.6 for upper and centerline of MR chart, respectively.

2. Phase II

In the present study four control charts were identified as being good candidates, namely MCEWMA with tracking signal, Ts, and EWMAST charts, included in the 1st approach; residual control chart (SCC) and residual EWMA chart, considering the 2nd approach.

The methodology and formulas used to construct the first two charts follows the original references, namely Montgomery and Mastrangelo [5] for MCEWMA and Zang [9] for EWMAST. Those three control charts, based on EWMA statistics, were modeled in MatLab®'s software, using Eq. (1.5) to obtain the autoregressive first order model, where errors are independent and identically distributed with mean zero and standard deviation of 36.0. The chart parameters were obtained by simulating data sets of 4,000 values, repeated 10,000 times. For EWMA of residuals and EWMAST, we considered the same smoothing constant (θ), equal to 0.2. The in-control ARL was fixed on 370, establishing a common performance comparison platform between all candidate control charts. The estimates of control chart parameters are shown in Table 1.1. Mean-square errors are presented in parenthesis in front of each related parameter.

Once control limits for all control charts are established, a competitive analysis was performed by considering the different types of changes that may occur in a process such as mean shifts and disturbances in model parameters. The simulation conditions were the same as in the previous study. The simulation results for the four control charts are presented in Table 1.2 and their corresponding ARL's and

Table 1.1 Estimates of control charts parameters obtained by simulation for the numerical example

	Control limit ($ARL_{IC} = 370$)	Chart parameters
EWMAST	$L^{EWMAST} = \pm 2.542$	$\hat{\sigma}_{EWMAST(0,2)} = 28.299$ (2.9170)
MCEWMA	$L^{MCEWMA} = \pm 2.542$	$\hat{\theta}_{min} = 0.445$ (0.0322) and $\hat{\sigma}_p = 41.5448$ (2.1421)
EWMAres	$L^{EWMAres} = \pm 14.166$	

Table 1.2 ARL's and SDRL (in parentheses) for SCC, EWMAres, EWMAST and MCEWMA charts

Shift size δ	SCC $K = 3.000$	EWMAres $K = 2.857$	MCEWMA $K = 3.308$	EWMAST $K = 2.542$
0.0	369.02 (368.435)	369.82 (360.634)	370.29 (529.281)	370.38 (360.791)
0.5	155.71 (155.177)	36.91 (30.765)	233.85 (459.974)	33.28 (26.472)
1.0	45.19 (43.629)	10.83 (5.890)	60.86 (246.139)	10.58 (5.028)
1.5	16.03 (14.557)	6.21 (2.288)	9.42 (81.872)	6.59 (1.893)
2.0	7.29 (5.766)	4.59 (1.288)	3.54 (23.954)	5.17 (1.052)
2.5	4.22 (2.694)	3.77 (0.840)	3.01 (0.166)	4.44 (0.700)
3.0	3.01 (1.423)	3.31 (0.612)	3.00 (0.053)	4.01 (0.545)

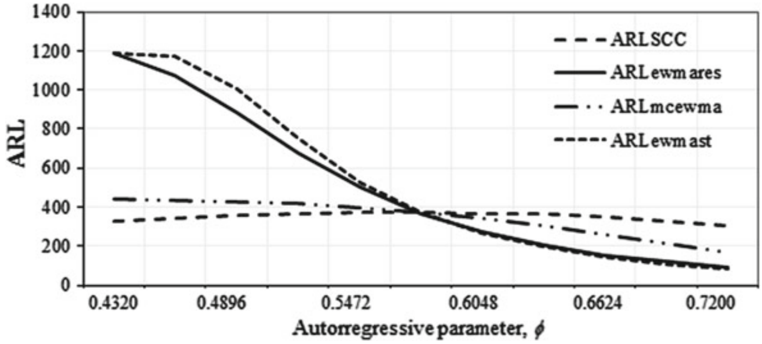

Fig. 1.3 Sensitive analysis on changes to autoregressive parameter, ϕ

SDRL's for the mean shifts were determined. The parameter is the size of the mean shift, measured in terms of the standard deviation (new mean = $\mu + \delta\sigma$) and with 0.5 increments.

Six changes with 5 % interval in autoregressive parameter ($\phi = 0.597$) were considered in what respects to model parameter disturbances (illustrated in Fig. 1.3).

Both sensitivity analysis methods evidence that EWMAres and EWMAST charts are the best performers in the autoregressive process in the study. Moreover, both present a similar behavior. As expected, SCC and the MCEWMA charts show poor sensitivity when detecting small to moderate shifts in mean, although they exhibit robustness in the presence of model parameter disturbances (Fig. 1.3). In contrast, EWMAres and EWMAST charts decrease their sensitivity whenever the autoregressive parameter decreases and increase their sensitivity whenever the autoregressive parameter increases.

1.5 Conclusion

Whenever statistical process control monitoring is to be used, great care should be taken to ensure that control chart requirements such as data independence are fulfilled. Ignoring data correlation has direct consequences regarding control chart performance deterioration (increased number of false alarms or decreased sensitivity). Through a case study, the present work evidences the key issues that should be taken into account in the presence of data autocorrelation. The role of simulation is demonstrated to be of great relevance not only to define the control limits that are able to converge on a single ARL value for all charts being used but also to obviate their comparative performance analysis. Considering process dynamic characteristics, AR(1), and taking into account the objective of detecting little to moderate disturbances in the process mean, the best choice dictates the use of EWMAST chart and EWMA residuals.

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Chapter 2
Evolution Mechanism of Scale Invariant Knowledge Network Influenced by Exogenous Factors

Ziyang Geng, Li Zhang and Xin Gu

Abstract Scale invariant knowledge network is always not formed for some specific objectives. Exogenous factors can not make the knowledge state changing synchronous through the existence purpose of knowledge network. Its influence will appear gradually depending on network nodes' asynchronous cognitive through more complex channels. Based on the power architecture reflecting how exogenous factors promote knowledge network's evolution, the function analytic solution has been given according to mathematical model considering both of individual communication channel and group spreading channel. Further more, computer simulation about how power architecture features affect knowledge network's evolution has been given too.

Keywords Exogenous influence · Scale invariant · Knowledge network's evolution · Dual channel spreading

2.1 Introduction

There is no uniform definition of knowledge networks by now. In the earliest definition given by Bechmann [1], knowledge network was described as an institution or activity for knowledge creation and spreading. Andreas pointed out that knowledge network is knowledge's creation and spreading on all the levels of individuals, groups, within organizations and between organizations [5]. Such knowledge

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_2,

network (we call it the first type network) is formed for specific purpose. Apart from the first type network, another type knowledge network is loose carrier for knowledge flowing. This type network (we call it the second type network) not only has no specific purpose and clear boundary but also has changeable structure. NSF defines knowledge network to be a social network which is an international communicating network providing knowledge and information and covering different languages and disciplines.

Besides above two types, the third view is knowledge network is not formed for specific purpose and is scale stable relatively which means the collection of network nodes is stable relatively. We call this type network the third type network. Kobayashi defined knowledge network is some kind of system formed by collection of nodes and relationships between them. He made the nodes stand for the discrete situation of human settlements which have concentrate knowledge production capacity and permanent activity ability [2].

Researches about knowledge network cover fields of knowledge network's formation, performance, coordination, evolution etc. Relatively speaking, researches about knowledge network evolution are less than them in other fields. Ritter et al thought enterprise knowledge network has features of dynamic and embeddedness and relationships between nodes are based on the combination of autonomy and interdependence. He believed the communication rules will promote or control knowledge flowing and then influence enterprise ability's developing [3]. Cowan et al studied the dynamic process of knowledge evolution in network type industry. He not only compared the influences of transferring knowledge random and under normal system to knowledge network evolution but also made simulation for corresponding models [4]. The researches of knowledge network evolution are mainly about the first type network while little about other two types.

The third type knowledge network can be seen as transition type between the first type and the second type. It will be helpful for research of the second type network's evolution to find out some rules of the third type network's evolution.

The main feature of the third type knowledge network is stable scale that means the nodes collection is relative stable. But this type network is not formed for specific purpose, the node relationship structure will change dynamic and the changing regularity is weak. Taking into account of such situation, this article will measure the degree of knowledge network evolution based on the degree of knowledge change.

The direct reason of knowledge change is demand for new knowledge while the more deep reason is the nodes' adaptive behavior for external environment changes. When one external factor appears, its influence can not push all the network nodes change their knowledge status synchronous because there is no specific purpose relating to knowledge network's existing. So some more complex channels will be useful to make nodes to be cognitive of the external factor and then to change their knowledge status. This article will discuss the evolution mechanism considering these complex channels.

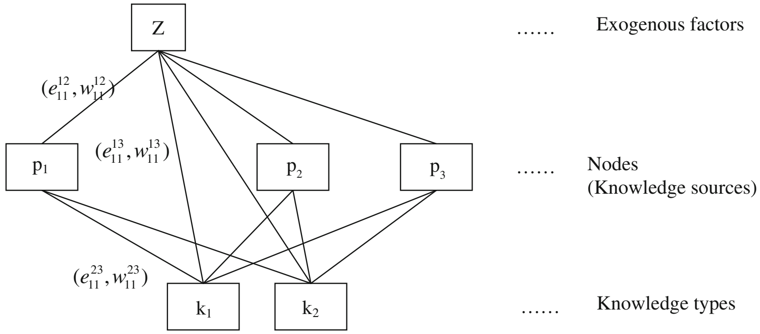


Fig. 2.1 Exogenous factor's power structure for knowledge network evolution

2.2 Exogenous Factor's Power Structure and Effect Way

2.2.1 Power Structure

We make Z stands for an external factor and make $I = I(P, K, E, W)$ stands for a scale invariant knowledge network (for short as knowledge network). $P = (p_1, p_2, \cdots)$ is the node collection and $K = (k_1, k_2, \cdots)$ is the knowledge type collection. $E = (e_1, e_2, \cdots)$ stands for the undirected edges between P and K. $W = (w_1, w_2, \cdots)$ stands for the weights of $E = (e_1, e_2, \cdots)$. Edges mean there are relationships between nodes and knowledge types. Weights mean the degrees of nodes' knowledge types and $w_x \in [0, 1], x = 1, 2, \cdots$. If one node does not have one specific knowledge type, the weight of the corresponding edge is zero. Z and $I = I(P, K, E, W)$ form the power structure of knowledge network evolution commonly (Fig. 2.1).

We denote:

1. the edges and weights between Z and nodes in Fig. 2.1 as $E^{12} = \left(e_{11}^{12}, e_{12}^{12}, \cdots\right)$ and $W^{12} = \left(w_{11}^{12}, w_{12}^{12}, \cdots\right)$.
2. the edges and weights between Z and knowledge types as $E^{13} = \left(e_{11}^{13}, e_{12}^{13}, \cdots\right)$ and $W^{13} = \left(w_{11}^{13}, w_{12}^{13}, \cdots\right)$ with $w_y^{12} \in [0, 1], y = 1, 2, \cdots$ and $w_z^{13} \in [0, 1], z = 1, 2, \cdots$. The edges and weights between nodes and knowledge types are E and W. Here we denote them as $E = E^{23} = \left(e_{11}^{23}, e_{12}^{23}, \cdots\right)$ and $W = W^{23} = \left(w_{11}^{23}, w_{12}^{23}, \cdots\right)$.

There are three situations for the meanings of edges and weights in Fig. 2.1.

1. E^{12} means nodes can perceive exogenous factors and its weights stand for nodes' sensitive degrees. One weight is bigger, the understanding of corresponding exogenous factor is better. On the contrary, one weight is smaller, the understanding of corresponding exogenous factor is worse.

2. E^{13} means current knowledge types have probability to change their status influenced by exogenous factor and its weights stand for the size of possible space for change. The bigger one weight is, the larger space size corresponding knowledge type will have while it is easier influenced by exogenous factor. On the contrary, one weight is smaller, the space size is smaller while knowledge type is harder to change its status.
3. E^{23} means knowledge types nodes have and its weights stand for the types' degrees. One weight is bigger, the corresponding degree is higher. One weight is smaller, the corresponding degree is lower.

Because the scale is invariant, the final result of power from exogenous factor will reflect in changes of knowledge types. In each triangle formed with three nodes and three edges both of them are picked from three node levels in Fig. 2.1 randomly, the knowledge network's change will occurs in such a small environment only when every weight of the three edges is not zero. We will call triangles every weight is nonzero to be effective triangles and triangles have edge weight is zero to be null triangles.

For each effective triangle, actual knowledge type revise action is always risk even the node is sensitive or the changing space is large. So some nodes maybe will not change their knowledge types under exogenous factor's influence. For those nodes going to change, the changing times are not synchronous too.

The process of knowledge types' changing is always a gradual process from point break to surface break: there are must some nodes of foresight will react to exogenous factor with changing their knowledge types and their neighbors will act like them next thus the exogenous factor's influence will gradually expand. This process can be seen as predictable overall and there are only positive revise because of knowledge's indelible feature.

Further more, we consider the concrete ways in which effective triangles' revise their knowledge types. The revises may happen in predictable generating ways or in unpredictable emerging ways. A concrete way will depend on knowledge type's technical property, node's investment policy, cooperation process and mechanism of knowledge creation, external environment pressure etc. So a concrete way relates not only to effective triangle's small environment but also external large environment with complex domain features.

According to above analysis, the power structure in Fig. 2.1 can be transferred to Fig. 2.2.

In Fig. 2.2, each edge of every effective triangle has nonzero weight and the relationships between these triangles are the relationships between knowledge sources in them. We denote the collection of edges as $E = \left(e_1^1, e_1^2, e_1^3, e_2^1, e_2^2, e_2^3, \cdots\right)$ and the collection of weights as $W = \left(w_1^1, w_1^2, w_1^3, w_2^1, w_2^2, w_2^3, \cdots\right)$.

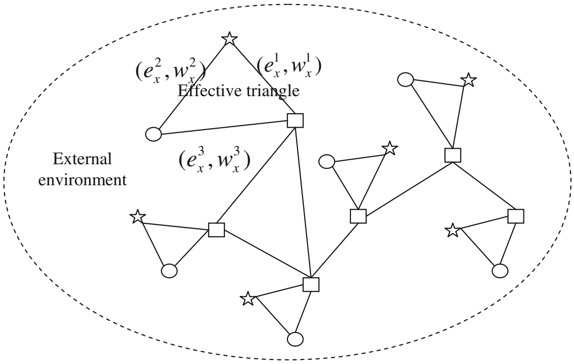


Fig. 2.2 Exogenous factor's power structure based on effective triangle. *Note Star* stands for exogenous factor, *square* stands for node (knowledge source), *circle* stands for knowledge type

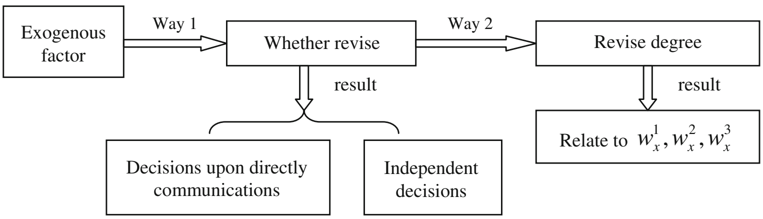


Fig. 2.3 Effect way and result of exogenous factor's power

2.2.2 *Effecting Way*

There are two effecting ways of exogenous factor (Fig. 2.3). The first is to influence knowledge sources' decision about whether revise knowledge types or not. The second is to influence the degree of revise.

The result of the first way has two situations. One is exogenous factor expands its influence through direct communication between knowledge sources and then the proportion of active sources bigger and bigger. Another one is knowledge sources decide their revise actions independently.

The result of the second way relates not only w_x^1 and w_x^2 but also w_x^3.

Among these two ways, the second way is follow-up of the first way and its effective range will not exceed the first way's range too. Specifically, the knowledge type's revise degree belongs to the effective triangle the first way point out. So the first way is the main trail for exogenous factor's influence.

For the two results of the first way, it is the main one that expanding influences through direct communication. This is common sense that brilliant organizations or persons are always minimum ones. So the second result of the first way will be seen as exception of the first result.

2.3 Model of Power Mechanism

There is a situation in epidemics spreading that virus spreads through direct touching and infected person can not be cured, such as HIV. For this situation, SI model based on famous SIR model can be used to explain its spreading mechanism. The exogenous factor's influence spreading is similar to such epidemics' spreading while has its particularity. The similar respect is knowledge's indelible feature makes the result of knowledge revise is irreversible. The particularity is one knowledge source's revise action will be known by others rapidly through highly developed knowledge communication channel and then the knowledge source's action decision will influenced not only by direct communication relationship between each other but also by the active atmosphere made by those sources who have done their revise decisions.

The spreading channel of exogenous factor's influence will be divided into two types. One is individual communication channel which means expanding through neighbor's communication, just like epidemics' spreading. Another one is group spreading channel which means knowledge source' cognition or judgment about exogenous factor's overall influence will promote its own probability of revise action.

It is possible that knowledge source will be "infected" while its neighbors are all "healthy". That is the group spreading channel might work without the individual communication channel. Just like independent infected case because of variation is ignored in research of epidemics spreading, we make hypothesis:

Hypothesis 1. when individual communication channel and group spreading channel are all effective, group spreading channel can only effect through individual communication channel.

We call a node of knowledge source who decide to revise its knowledge type to be excited state node and the other nodes to be unexcited state nodes. We use direct communication proportion δ to stands for the probability of an unexcited state node transfer into excited state in unit time when it only touches an excited state node. δ is a stable parameter. We use group spreading proportion δ' to stands for the probabilities of an unexcited state node transfer into excited state in unit time when both of the two spreading channel are all effective. δ' is unstable because the density $i(t)$ of excited state nodes is changing.

Hypothesis 2. when both of the two spreading channel are all effective, δ' will rise with the increase of $i(t)$ and

$$\delta' = \delta\varepsilon[1 + i_t], \tag{2.1}$$

δ is direct communication proportion. ε is group effect parameter which means the group atmosphere's influence result to δ.

In Eq. (2.1), there must be $\varepsilon \leq \frac{1}{2\delta}$ because of $\delta' \leq 1$.

Group atmosphere can make negative effect which means δ' could be smaller than δ. One reason for this situation may be the side effect of sentiment for new things. So the limit of ε depends on whether group negative effect or not.

If there is not negative effect, we will have, from $\delta' \geq \delta$.

If there is negative effect, we will have $\varepsilon \geq 0$ from $\delta' \geq 0$. So the range of ε are

$$\begin{cases} \frac{1}{1+i_0} \le \varepsilon \le \frac{1}{2\delta}, & \text{no negative effect} \\ 0 < \varepsilon \le \frac{1}{2\delta}, & \text{negative effect.} \end{cases} \tag{2.2}$$

The change rate π stands for revised knowledge type's average increase degree. Except the influence from external environment, δ' and π are also restricted by the specific environment in effective triangle. Such restriction reflects on the weights of effective triangle.

The probability will be higher only when knowledge source is sufficient cognitive of exogenous factor, the revise space is large enough and current knowledge foundation is better. The final revise degree is affected by all these three factors. The easier for spreading, the bigger π is. It is mean that the directions of influences on δ' and π are same.

Hypothesis 3. the changing directions of δ' and π are same and $\pi = \tau\delta'$. τ is synchronous parameter. We denote density of unexcited state node as $S(I)$. So we have $s(t) + i(t) = 1$. We denote ψ as the average degree of knowledge types before exogenous factor appearing and $\phi(t)$ as the function of average degree of knowledge type changing with time after exogenous factor appearing.

First of all, we build model referencing SI model for the situation only existing individual communication channel. We call this model basis model below.

$$\begin{cases} \frac{ds(t)}{dt} = -\delta i(t)s(t) \\ \frac{di(t)}{dt} = \delta i(t)s(t) \\ \varphi(t) = \psi + \pi\psi i(t) = \psi(1 + \tau\delta i(t)) \\ i(0) = i_0. \end{cases} \tag{2.3}$$

Using method of changing constant, we have $i(t) = \frac{1}{1+\left(\frac{1}{i_0}-1\right)e^{-\delta t}}$. So

$$\varphi(t) = \psi\left[1 + \tau\delta\frac{1}{1+\left(\frac{1}{i_0}-1\right)e^{-\delta t}}\right].$$

The second step is to build model for situation both of two spreading channels are all exist:

$$\begin{cases} \frac{ds(t)}{dt} = -\delta\varepsilon[1 + i(t)]i(t)s(t) \\ \frac{di(t)}{dt} = \delta\varepsilon[1 + i(t)]i(t)s(t) \\ \varphi(t) = \psi(1 + \tau\delta' i(t)) = \psi[1 + \tau\delta\varepsilon[1 + i(t)]i(t)] \\ i(0) = i_0. \end{cases} \tag{2.4}$$

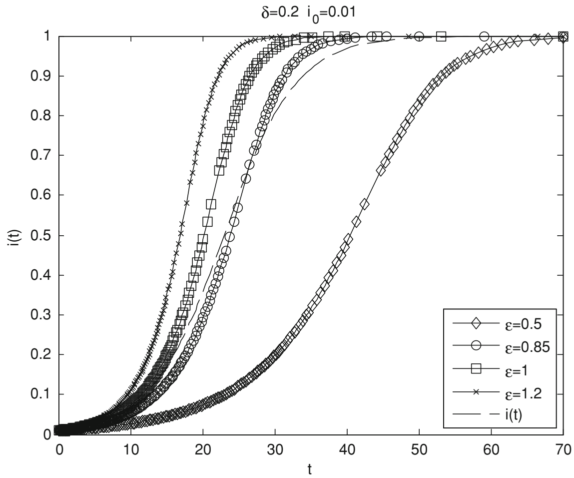


Fig. 2.4 Growth trend of $i(t)$ when $\delta = 0.2$, $i_0 = 0.01$ according to double channel model

Using method of changing constant too, we have:

$$i(t) = \left[\frac{1}{1 + \left(\frac{1}{i_0^2} - 1 \right) e^{-2\delta\varepsilon t}} \right]^{1/2}, \tag{2.5}$$

$$\begin{aligned} \varphi(t) &= \psi(1 + \tau\delta' i(t)) \\ &= \psi \left[1 + \tau\delta\varepsilon \left[\left(\frac{1}{1 + \left(\frac{1}{i_0^2} - 1 \right) e^{-2\delta\varepsilon t}} \right)^{1/2} + \frac{1}{1 + \left(\frac{1}{i_0^2} - 1 \right) e^{-2\delta\varepsilon t}} \right] \right]. \end{aligned} \tag{2.6}$$

2.4 Model Analysis

We assumed there is group negative effect during the process of evolution which means apparent hesitation morale exists in prophase of the process and direct communication proportion will not be high. As to the double channel model, we make $i_0 = 0.01$, $\delta = 0.2$ which means the maximum value of ε is 2.5 and the thresholds of for negative effect are $\varepsilon_{+-} = 1/(1 + i_0) \approx 1$. With $i_0 = 0.01$, $\delta = 0.2$, Fig. 2.4 show us the growth trend of $i(t)$ when ε are respective 0.5, 0.85, 1, 1.2. In Fig. 2.4, the dashed line stands for the growth trend of $i(t)$ when $i_0 = 0.01$, $\delta = 0.2$ according to basis model.

Three important questions are reflected from Fig. 2.4. The moments the lines turn from convex trend to concave trend reflect the moment of exogenous factor's influence from strong to weak. The first question is the specific positions of the moments. We call these specific positions to be peak moment.

Because of the negative effect, some lines (for example $\varepsilon = 0.85$) will intersect with the line under basis model and then transcend it while some other lines (for example $\varepsilon = 0.5$) will never transcend the line under basis model. The second question is the range of ε during which the corresponding lines will conquer the negative effect and the third question is the conquer moments.

We call the range of ε during which lines can conquer the negative effect to be positive range and call the corresponding moments to be positive moment.

First of all, we will analyze the peak moment. Calculating quadratic differential of Eq. (2.5), we have

$$i''(t) = \frac{-2\delta^2\varepsilon^2\left(\frac{1}{i_0^2}-1\right)e^{-2\delta\varepsilon t}\left[1+\left(\frac{1}{i_0^2}-1\right)e^{-2\delta\varepsilon t}\right]+3\delta^2\varepsilon^2\left(\frac{1}{i_0^2}-1\right)^2 e^{-4\delta\varepsilon t}}{\left[1+\left(\frac{1}{i_0^2}-1\right)e^{-2\delta\varepsilon t}\right]^{5/2}}. \tag{2.7}$$

It is not certain for numerator's positive or negative cases in Eq. (2.7). So we have at peak moment

$$-2\delta^2\varepsilon^2\left(\frac{1}{i_0^2}-1\right)e^{-2\delta\varepsilon t_m}\left[1+\left(\frac{1}{i_0^2}-1\right)e^{-2\delta\varepsilon t_m}\right]+3\delta^2\varepsilon^2\left(\frac{1}{i_0^2}-1\right)^2 e^{-4\delta\varepsilon t_m} = 0. \tag{2.8}$$

From Eq. (2.8) we have $t_m = -\frac{1}{2\delta\varepsilon}\ln\frac{2}{\frac{1}{i_0^2}-1}$.

Secondly, we will analyze positive range and positive moment. Based on Eq. (2.1), conquering negative effect means the change of δ' from less than δ to bigger than δ. That is: $\delta\varepsilon(1+i(t)) > \delta \Rightarrow \varepsilon > \frac{1}{1+i(t)}$. Because of

$$\lim_{t\to\infty}\left[\frac{1}{1+\left(\frac{1}{i_0^2}-1\right)e^{-2\delta\varepsilon t}}\right]^{1/2} = 1,$$

ε must meet $\varepsilon > \frac{1}{1+1} = 0.5$, so positive range is $\varepsilon \in \left(0.5, \frac{1}{1+i_0}\right)$.

For a given ε, positive moment must meet:

$$\delta\varepsilon(1+i(t_c)) = \delta \Rightarrow t_c = -\frac{1}{2\delta\varepsilon}\ln\frac{\frac{1}{\left(\frac{1}{\varepsilon}-1\right)^2}-1}{\frac{1}{i_0^2}-1}.$$

2.5 Influence of Power Structure's Feature to δ

In Fig. 2.2, features of power structure are decided by features of effective triangles while features of effective triangles are reflected in their weights of edges. The influence of weights to evolution is mainly reflected in influence to δ and π. Because δ and π change in the same direction, we will make our analysis focus on the influence of weights to δ.

More sensitive of knowledge source for exogenous factor or larger of the knowledge type changing space, bigger the possibility of knowledge source's changing action which means the bigger of δ. Different from diminishing return for resource input in physical manufacture, it is increasing return in knowledge manufacture. Knowledge sources will have more motion to revise their knowledge types when degrees of knowledge types are higher and then will be bigger. Overall, weights of edges and δ are changing in the same direction.

Hypothesis 4. affection way to δ from effective triangles is:

$$\delta = \lambda (w^1)^a (w^2)^b (w^3)^c,\ w^1 = \frac{1}{N}\sum_{x=1}^{N} w_x^1,\ w^2 = \frac{1}{N}\sum_{x=1}^{N} w_x^2,\ w^3 = \frac{1}{N}\sum_{x=1}^{N} w_x^3. \tag{2.9}$$

N is the total of effective triangles in knowledge network. $a \geq 0$, $b \geq 0$, $c \geq 0$ are elasticity parameters. One elasticity parameters is bigger, the corresponding weight's influence to δ will be weaker. $0 < \lambda < \frac{1}{(w^1)^a (w^2)^b (w^3)^c}$ is transformation parameter for influence effective triangles to δ. Effective triangles are established from the perspective of changing knowledge to response exogenous factor, but knowledge changing will influence knowledge source's business process deeply too. So we need consider influence to δ rom some other external factors such as business strategy, business status etc. These influences will enlarge or shrink the influence $(w^1)^a (w^2)^b (w^3)^c$ to δ.

Given λ and $a,\ b,\ c$, the influence from edges to δ will depend on how to get average weights. We assumed each edge's weight fit normal distribution. So the standard deviation and mean will be key roles in affecting average weights.

We set the total of knowledge source nodes to be 100, the total of knowledge types to be 30, the average types hold by every knowledge source node to be 7. Given $\lambda = 2,\ a = b = c = 1$, we assumed each weight fit normal distribution. We set mean of each weight to be 0.5 and the range of standard deviation to be $[0.1,\ 0.3]$. Figure 2.5 show us the relationship between standard deviation change and δ change.

From Fig. 2.6 we can see that δ increases smoothly and linear with mean's increasing and the speed of increasing is fast: δ changes in magnitude more than 0.3 while mean changes in magnitude about 0.2. So influence on δ from mean is obvious bigger than that from standard deviation.

Fig. 2.5 Relationship between standard deviation change and δ change

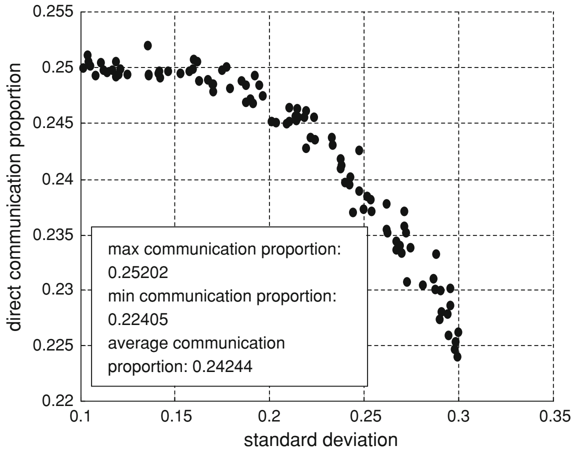
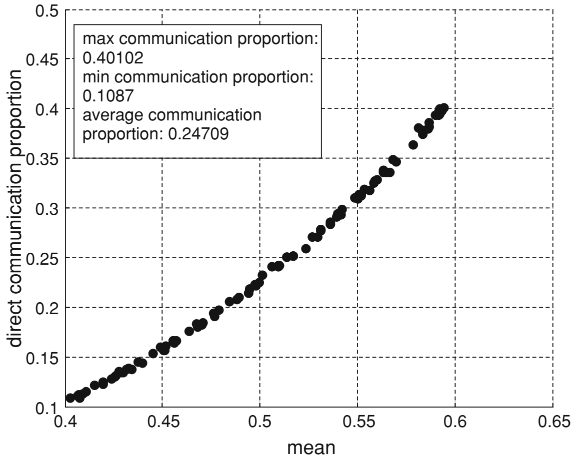


Fig. 2.6 Relationship between mean change and δ change



Acknowledgments This research is supported by: (1) Sichuan Philosophy and Social Science Emphasis Research Base Project (Xq13C03); (2) Sichuan Philosophy and Social Science Planning Project (special issue) (SC13BJ04); (3) Science and Technology Development Fund Project of Chengdu University of TCM (RWMS201304) and (4) Sichuan Science and Technology Project_Soft Science Research Project (2014ZR0133).

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Chapter 3
Assessment of Hardware Product Design Defects by Fuzzy Neural Network Based on Genetic Algorithm

Huimeng Zheng, Weidong Liu, Chengdi Xiao and Weili Hu

Abstract The assessment on hardware design defects plays an important role in the product development process. In order to improve the design quality through mitigating design defects, a model for assessing hardware product design defects is developed in this paper based on the design defects formation mechanism of product. A novel assessment method by applying fuzzy theory, genetic algorithm and neural network is proposed to construct assessment model. Assessment index is quantified by fuzzy language description. Fuzzy BP neural network tuned by genetic algorithm with the purpose of optimizing the connection weights and avoiding local minimum is used to evaluate probability of product design defects occurrence. The results obtained in this study demonstrated that the assessment model had excellent capabilities with a high accuracy and good training speed, thus provides an effective tool for assessing design defects of hardware product.

Keywords Neural network · Hardware product · Design defects · Defect assessment · Genetic algorithm

3.1 Introduction

The product development process involves lots of complex, difficult and uncertain decision-making procedures, featured with high risk in terms of product design defects. In the quality engineering field, the design defect is defined as concrete product's quality characteristics formed during R&D phase fail to meet expectation or requirements. Numerous studies on product development and project risk management have indicated the inherent uncertainty in R&D may lead to the final

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_3,

failure of product. Therefore, it is vital for company to construct risk management system, either through framing risk control process or establishing performance evaluation [19]. The modeling on decision support system (DSS) and risk evaluation of product development is crucial to project risk management [4]. Several literatures have revealed Bayesian belief networks' application on project risk management for software development [5, 12].

Design defects may appear in various forms thus have diverse research direction. A set of expert rules are developed via analytical simulation on the assembly process and investigation of assembly practice, in order to predict the misalignment defects in assembling products [3]. Research on classification of design defects is conducted to decompose it as structural defects, functional defects, performance defects, craft defects and etc [13]. The connection network model is established between design defects and defects factors. Some studies have distinguished technical risk from performance risk [21]. As the complexity of products increases, single department or company becomes incapable of developing the entire product, which leads to the wide spread of concurrent and distributed development. To manage the resulting organizational complexity, modeling for detecting design defects is highly demanded in the entire product life cycle, and it should explicitly reflect and address the nature of concurrent development [15].

Although the uncertainty and randomness of product design defect make it fail to be detected apparently in development process, many methods have been proposed to evaluate the risk involved in many fields, such as failure mode effect analysis [1, 9], probability risk assessment [6, 17], the risk matrix method [7], the system dynamics method [14], the graphical evaluation and review technique (GERT) [11] and the Bayesian network [2, 8]. Product design defects are formed in the product design process in terms of subjective or objective analysis and judgment. Limited by technical, materials, financial, time or other resources, there is a risk of design defects augment in the product design and development process. If design defects are not identified and resolved in time and the products with innate flaw are released into market, it may harm the customer's benefits or even jeopardizes the company's survival in the future. Thus, it is positive and significant to construct the assessment model for design defects of hardware product, in terms of improving product design quality through controlling design defects during development process.

The process of product design and development involves with numerous influencing factors that may lead to design defects, such as product design information, design management, design resources and so on. It is found that nonlinear relationship exists between influencing factors and design defects, thus generating the complexity and uncertainty of design defect assessment. Meanwhile, the neural network such as back propagation (BP) neural network, features with strong nonlinear fitting capabilities thus can be applied to solve nonlinear problems that traditional statistical method can hardly work out. In addition, the neural network possesses better self-learning, adaptation and generalization capabilities compared to traditional statistical method. Risk assessment methods based on neural network are widely used and good performance in the risk field is achieved [10, 16, 20].

Table 3.1 Design defect forming elements corresponding to design defect controlling elements

Design defect forming elements	Design defect control elements
Defect sources (defect factors)	Design research information, design requirements, conceptual design products, detailed design products
Defect carriers	Personnel, fund, equipment, design concept, technology information
Defect flows	Fund flow, technology flow, equipment flow, information flow, personnel flow
Inducement of defect	Design ideas, design style, design benefits, design cycle
Conduction path of design defect	Design flow
Defect acceptor	Design environment, design capabilities, design technology, design organizations, design coordination, process information
Defect threshold	Design environment, design management, design resources, design comprehensive quality, design information

3.2 Assessment System for Hardware Product Design Defects

To achieve early alert on design defects and implement controlling strategy in time, it is necessary to construct an assessment system to predict probability of product design defects occurrence. A rational design defect evaluation system is established based on its formation mechanism in this paper.

1. Formation of Hardware Product Design Defect

A rational evaluation index system is an important prerequisite for achieving successful design defects assessment. As the product design process is full of risks and design defect belongs to design risk events. Based on risk theory, this paper first analyzes formation mechanism of product design defects based on risk conduction theory. Stimulated by design defect incentives, defect factors converge to defect flows by relying on some certain carrier. Defect flows spread and diffuse through certain path or channel and once the strength of defect flows is greater than the defect threshold, defective factors will be conducted to various stages of product design, resulting the design deviation between the desired quality level and the actual one, thus product design defect is forming. The relationship between design defect forming elements and design defect controlling elements are shown in Table 3.1.

2. Determination of Assessment Index for Product Design Defects

The state defect sources, defect carriers' ability, conduction capability of defect pathway, resistance on defects from receiver are four core elements of design defect formation and conduction. The core elements are characterized by nine control units: environment (e_1), information (e_2), technology (e_3), ideas (e_4), personnel (e_5), equipment (e_6), funds (e_7), processes (e_8), benefits (e_9), and they are chosen as assessment indexes for product design defects.

Table 3.2 Please write your table caption here

P (%)	Defect degree	Description
$P \geq 20$	Very big	Almost certainly occur
$10 \leq P \leq 20$	Big	Be likely to occur
$1 \leq P \leq 10$	Medium	May occur
$0.5 \leq P \leq 1$	Small	Unlikely to occur
$P \leq 0.5$	Very small	Less prone to occur

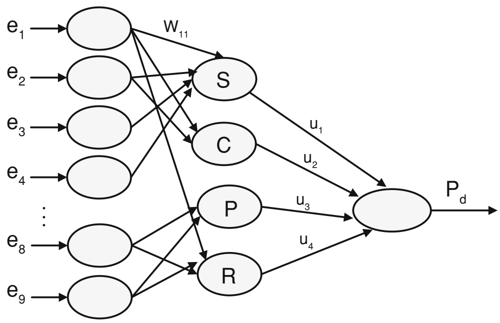

Fig. 3.1 Fuzzy neural network model of design defects assessment

3.3 Design Defect Assessment Model Based on BP Neural Network

The BP (back propagation, BP) neural network, as a typical feed forward network, is the most frequently used for neural network training and validating. BP neural network is applied to construct assessment model combined with experts' assessment knowledge and fuzzy logic language description. Since the product development process is impacted by design defect factors, the concept of design defect degree is introduced to quantize the occurrence of product design defect, shown in Table 3.2.

3.3.1 Construction of Defect Assessment Model

Fuzzy neural network model of design defects assessment is shown below in Fig. 3.1. It consists of three layers: the input layer, hidden layer, and output layer. Take nine indicators $(e_1, e_2, \cdots, e_9)$ mentioned previously are taken as the neural network input layer which are independent random variables. The state defect sources S, defect carriers' ability C, capability of defect pathway P, resistance on defects from receiver R are selected as hidden layer of neural network. Weight u_1, u_2, u_3, u_4 are defects preference factor which greatly affects the algorithm performance and output variable P_d is the output layer of the network which denotes design defects degree.

3.3.2 Genetic Algorithms Optimize BP Neural Network

The initial weights and thresholds are randomly selected and artificial neural network trained by BP algorithm suffers from converging too slowly and being easily trapped into a local minimum. Hence, genetic algorithm (GA) is applied to solve the problem. GA is an advanced optimizing algorithm with relatively strong capability to search global optimum. The process of GA searching optimized value is a successive iteration. Such a group searching enables genetic algorithm to break through neighborhood search restriction during the searching process, hence distributed information collecting and exploration on entire solution space can be realized. The best individual that meets the requirement thus can be found. The training on neural network is divided into two parts: first, using genetic algorithms to optimize the initial weights and thresholds of the network, and then training data is input to the network to get optimized model.

The optimization process of genetic algorithm applied on BP neural network is shown in Fig. 3.2 and the relevant procedures are shown as follows:

1. Population initialization

Population initialization includes coding and generating the initial population. Randomly generate N initial structural data strings, then code for each string. The individual weights and thresholds of neural network are sequentially compiled in an array of real numbers, which is a chromosome of genetic algorithm, the length of chromosome is L:

$$L = R_1 \times R_2 + R_2 \times R_3 + R_2 + R_3. \tag{3.1}$$

In Eq. (3.1), R_1 is the number of inputs, R_2 is the number of hidden layer nodes and R_3 is the number of outputs. Genetic manipulation is carried out in this chromosome group.

2. The objective function and fitness function

Squared error of the neural network is selected as the objective function of genetic algorithm and thus the evaluation function of genetic manipulation is fitness function F, which can be expressed as below: $F = \frac{1}{\sigma}$.

3. Select, crossover and mutation

Selecting operation is executed according to fitness and selection rate. To get good cross-rate, part genetic of parent individuals exchange each other and reorganized by crossover operation, then produced new individuals. Mutation is applied to keep the diversity of chromosome and prevent premature so that global search can be achieved. Repeat the above operation until evolution generation meets the requirements or network error satisfies the termination condition. A set of weights and thresholds of BP neural network is found when training network error reaches minimization.

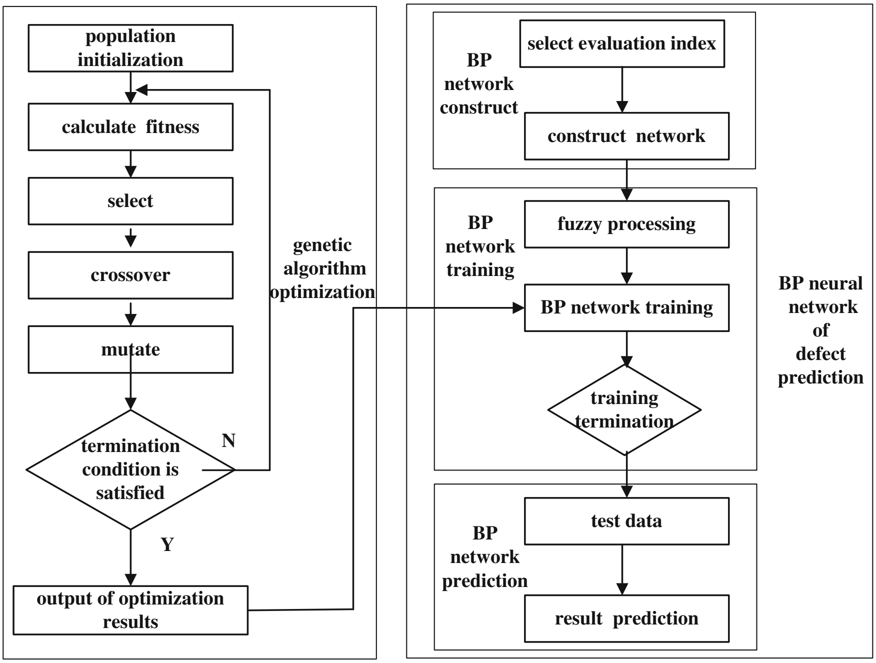

Fig. 3.2 Processes of genetic algorithm to optimize neural network

3.4 Simulation Application

3.4.1 Selection and Processing of Assessing Data

Choose hardware products with typical characteristic as research object, for example, automotive, aerospace products and home appliances. Data is obtained by score from enterprise experts and fuzzy processed then. Since the assessment index of defect factors is qualitative, it is improper to directly input to the neural work because only quantitative data is acceptable. Thus, fuzzy processed data is taken as the input of BP neural network. The steps are shown as follows:

1. Determine nine indexes based on the formation mechanism of hardware product design defects, $E = \{e_1, e_2, \cdots, e_n\},\ n = 1, 2, \cdots, 9$;
2. Construct the evaluation set based on fuzzy evaluation. Delphi was used to evaluate the value of defect factors and the indicators are divided into m levels, get evaluation set V, $V = \{v_1, v_2, \cdots, v_n\}$;
3. Experts give the judge set of each factor, membership vector of defects factors to evaluation set is defined as R_i, $R_i = \{r_{i1}, r_{i2}, \cdots, r_{i9}\}$, get membership matrix R;
4. Considering the value of each index in the evaluation set directly affects the design defects degree, assign each evaluation index with different weights. Set weight

Table 3.3 Partial comparative data

Number	1	2	3	4	5	6	7	8
Simulation output	0.00351	0.00751	0.00633	0.00573	0.00797	0.00425	0.00569	0.00359
Expert valuation	0.00423	0.0758	0.00672	0.00535	0.00756	0.00382	0.00529	0.00411
Error	0.00072	0.0007	0.00065	0.00038	0.00041	0.00043	0.00040	0.00052
Number	9	10	11	12	13	14	15	16
Simulation output	0.00378	0.00521	0.00845	0.00898	0.00742	0.00827	0.00624	0.00432
Expert valuation	0.0043	0.00476	0.00807	0.00939	0.00707	0.0079	0.00667	0.00477
Error	0.00052	0.00045	0.00038	0.00041	0.00035	0.00037	0.00043	0.00045
Number	17	18	19	20	21	22	23	24
Simulation output	0.00689	0.00543	0.00721	0.0162	0.00891	0.11342	0.32233	0.00368
Expert valuation	0.00761	0.00608	0.00682	0.01563	0.00845	0.11379	0.32178	0.00433
Error	0.00072	0.00065	0.00039	0.00059	0.00046	0.00037	0.00055	0.00065

distribution $W = (w_1, w_2, \cdots, w_m)$, form the fuzzy arithmetic and get:

$$B = W \cdot R^T = (w_1, w_2, \ldots, w_m) \begin{bmatrix} r_{11} & r_{21} & \cdots & r_{n1} \\ r_{12} & r_{22} & \cdots & r_{n2} \\ \vdots & \vdots & \ddots & \vdots \\ r_{1m} & r_{2m} & \cdots & r_{nm} \end{bmatrix}. \tag{3.2}$$

B means evaluation value of defects factors under certain evaluation which varies from (0, 1), thus can be used as input variables of BP neural network.

3.4.2 Simulation Results

Modeling and solving are carried out based on related functions in genetic algorithm package and neural network toolbox. The operating parameters in genetic algorithm to optimize BP neural network are shown as follows: initialization space value of the weight is from −1 to 1, the number of population is 100, the maximum number of evolution generation, select rate, crossover rate, mutation rates are 100, 0.09, 0.9 and 0.05 respectively. Based on the above settings, we get 300 sets data through fuzz processing and utilized as training data for neural network; 120 data sets are testing data and carried out for simulation experiment. The results of the simulation output are compared with the value evaluated by five experts with D-S evidential reasoning method applied [18]. As can be seen from Table 3.3, simulated result coincides to expert evaluation with relatively high accuracy.

In addition, initial error of weights and thresholds is 0.00087; training times is 100, error is 0.00045; when training times is 153, the error can meet the specified requirement. When neural network is optimized by genetic algorithm, training times reach 50 and error is 0.00032; training time is 103 the error can meet the specified requirement. From simulation results, the GA optimized neural network effectively improves the convergence speed.

3.5 Conclusion

To effectively control design defects in the product development process and improve the design quality of hardware product, assessment model of design defects is constructed based on the formation mechanism of product design defects by fuzzy theory, genetic algorithm and neural network. A novel neural network assess model is tuned by genetic algorithm combined with fuzzy theory to overcome local minimum problem and accelerate the training speed. Our results show that the proposed model is reliable and useful for the assessment the nonlinear relationship between defect factors and design defect. In short, this study indicated that the assessment model has good application prospects and is a practicable tool for assessing probability of product design defects occurrence.

Acknowledgments The authors gratefully acknowledge the enterprises that provide data and design experts who participate in works of data fuzzy processing. We also thank M.S. Li and Yang Liu for their suggestions and providing language help on the earlier version of this article. This research is supported by the National Natural Science Foundation of China (Grant No. 71161018).

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Chapter 4
Game Analysis and Improvement of the Medical Expenses Payment

Fang Qing, Li Luo, Ming Zhao and Qunrong Ren

Abstract Fee for Service is a widely used way of medical expenses payment. However, this kind of payment often stimulates the excessive medical services. This paper reveals the mechanism of excessive medical service through economic game theory. It is difficult to control health care cost under a single payment mode. Under the framework of new rural cooperative medical schemes, this paper presents a mixed payment and analyzes the game between Medical Insurance and hospital. Results indicate that choosing a mixed payment strategy according to certain probability distribution can always achieve the Pareto equilibrium solution of resource allocation and can also be helpful to control the excessive growth of medical expenses.

Keywords Medical expenses payment · Game theory · Fee for service · Mixed payment

4.1 Introduction

Social medical insurance, which is an important part of the country's social security system, has a pivotal position to maintain social stability and has played a huge role in the protection of workers' health and resist the risk of disease and so on. Since the implementation of the basic medical insurance system for urban employees in 1998, our country mainly focuses on expanding coverage, improving the level of

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_4,

compensation and strengthening service management. With universal coverage of basic medical security system, the control of the medical treatment cost is more and more important. At present, although free medical care security system has been abandoned in China, those phenomena-such as sharp raise of health care costs, the shortage and waste of medical consumption, and excessive and inadequate use in medical services, and so on-still increase. After a hospital provides services, its fees are mainly compensated by medical insurance institutions (hereinafter referred to as health care). Scientifically charging the payment for medical treatment can stimulate hospitals to provide high quality and appropriate medical services. The control of medical cost is a worldwide problem. Because the reasons for growth of medical expense are complex, the control is a long-term and difficult task. We must tackle the problem of a 3D (medical, health care, medicine) linkage. The reform of health care payment is a major means to control the cost, which has been adopted in the practice of most countries in the world.

Medical expense payments are specific methods used by social medical insurance institutions to hospitals for compensating costs of providing the medical services for the insured. There are two classes of payment: in advance and after. The payment can be roughly divided into five kinds, namely, Fee For Service, Service Unit, Diagnosis Related Group (DRG), Capitation, and Global Budget. At present, the more extensive practice in China is paid according to the service items, which belongs to the class of after payment. Under this mode of payment, paying party compensates according to the actual cost after the occurrence of medical service which is difficult to control costs effectively. From the experience and lessons of medical insurance in domestic and foreign countries, the single payment that pays according to the project is an important cause that made the medical costs rise too fast in the past few decades. Choose a reasonable payment of medical expenses is the key to control cost, and establish a diversified and mixed fee payment system is the direction of reforming and developing the payment of the basic medical expenses. At the same time, the form of payment will impact the behavior choice of hospitals and health care. This paper uses the method of game theory [2], from the benefits angle of hospitals and health care to discuss the behavior choice of hospitals and health care under different charge payments, and proves the rationality and superiority of the existence of mixed payments, then puts forward the policy suggestions for further reforming and perfecting medical insurance payments.

4.2 Literature Review

Through literature review, at present, the discussion of medical expense payment most focuses on the advantages and disadvantages of each way and its comparison in China. Zheng [15], Liang [5] etc do a comparative analysis on the medical insurance payment, put forward suggestions about advancing the reform of medical insurance payment system and establishing the control mechanism of medical insurance expenses actively. Meng and Chang [9] after comparative studying the settlement way of basic medical insurance of urban workers in Zhenjiang, Jiujiang and Qingdao, thinking that the settlement way is not only an effective means to control medical expense, but also an important factor which affect the relationship of medical, insurance and patients. Hu et al. [4] argue that single payment will lead to serious waste of medical resources eventually, due to the negative effect of path dependence. Then they propose to establish a diversified payment system which can prompt medical service institutions to raise health care's quality, reduce the medical cost and improve the efficiency of the use of medical resources. Qian and Huang [11] put forward that medical insurance payment should take combined payment and "clinic head" as the core, the "total budget" as the basic and mix "project pay", "Quota pay" and "diseases pay" and "head pay" together, make all kinds of payments cooperate with each other, get complementary advantages, control medical costs effectively and ensure medical insurance fund smooth and balance. Liu and He [6] based on the model in Michel and Naegelen [10] and the assumptions about medical institutions was risk averse agent, built a mixed medical insurance payment and do the numerical simulation on the turning point of mixed medical insurance payment and subsidies. Liu et al. [7] analyze the deep interest relationships among the current government, medical insurance institution, public hospitals and patients. Then they use the method of game theory, do a hybrid game analysis on medical insurance expenses controlling, and put forward the solutions.

Comprehensive the above literatures, we can conclude that there isn't exist a perfect payment, each payment has its own advantages and disadvantages. For most of payments, the main disadvantage can be compensated from other payment, and therefore need adopt the mixed payment. Adopting the mixed medical insurance payment has been the consensus of scholars and also the direction of reforming. But there is few literatures to prove why mixed payment is better than single payment, so this paper with the method of game theory, from the perspective of hospital and health benefits to prove the irrationality of single payment and the rationality and superiority of mixed payment.

4.3 The Game Analysis of Medical Insurance and Hospitals Under Fee for Service

When paid according to the service project, the compensation provided by the medical insurance is based on the number of medical services that provided by the hospital. The more the number of services provided by the hospital, the more the costs of compensation. In this way, it is easy to stimulate excessive medical services and is difficult to control health care costs. Even in the case of determining the price of medical services, health care providers still can improve health care costs by increasing the number of services.

In the medical market, "Say's Law" [13] is common. It means that medical supplies create medical needs, and hospitals are able to induce patients to consume

Table 4.1 The game model of fee for service

Medicare hospital	Cooperation	Noncooperation
Cooperation	(I, R)	$(I - S, R + S)$
Noncooperation	$(I + S, R - S)$	$(I - S, R - S)$

as much health care as possible. This is the phenomenon that health care providers use their advantageous information to induce patients to receive excessive medical services. In this induced demand, the patient is in a passive position. It is unreasonable medical needs which are not from their own will, but are the excessive demands stimulated by health care providers. Under our current health care system, it is directly proportional to the level of the hospital's income and medical expenses, so hospitals have a great incentive to induce the patients to do excessive consumption. Meanwhile, medical service is specialized service and doctors understand more about the disease severity, the effectiveness of the treatment, and the appropriateness of medical services and other information. In comparison, the insured often hold obedience attitudes due to lack of medical knowledge and the fear of the disease. Because the health insurances were excluded out of the process of medical treatment, they do not know the behavior of the hospital. In such a situation, the hospital which has both proponents and medical services dual identity will be able to implement induce to the insured demand easily. Here we will analyze the game against Medicare and hospital when the payments are made according to the service items. For clear expression, we firstly define the related matters in the game. In the game, we call hospital cooperation with medical insurance when the hospital does not hide medical information for medical insurance; otherwise, it is called the hospital noncooperation with medical insurance. Moreover, we call Medicare cooperation with the hospital when the Medicare reimburses the hospital medical expenses; otherwise, it is called the Medicare noncooperation with the hospital.

Assuming that the hospital with medical insurance in the condition of cooperation's revenue was I and R (I, R are greater than zero) unit, for the hospital, I units' income is from the reimbursement of medical expenses, and for health insurance, the R units' income is from its proper health insurance social benefits. Similarly, if any of the parties change the behavior of the state of cooperation, the cooperative equilibrium [14] will be broken and revenue of hospital with Medicare will be changed. Assuming the hospital turned to uncooperative and hide information will result in excessive medical services. If Medicare does not recognize their behavior and still reimburse medical expenses, then the hospital will get additional S ($S > 0$) units 'revenue and Medicare will lose S units' revenue. However, if Medicare identifies its behavior and refuses to reimburse medical expenses, then hospital will lose S units' earnings and health insurance will get S units' revenue. Assuming the hospital still has a cooperative attitude and does not hide the information to medical insurance, but Medicare chooses an uncooperative attitude (e.g., Medicare has recorded hospital's bad behaviors and given the attitude of distrust, not to reimburse medical expenses), then the hospital will suffer S units' lost, and Medicare will get additional S units' revenue. The game model is shown in Table 4.1.

In this game, assuming the probability of health insurance cooperation is $P(0 \leq P \leq 1)$, then, according to Table 4.1, when hospitals choose to cooperate, we can calculate the expected profit E_1: $E_1 = I * P + (I - S) * (1 - P) = I * P + I - I * P - S + S * P = I - S + S * P$. When hospitals choose noncooperation, calculate the expectation profit E_2 as: $E_2 = (I + S) * P + (I - S) * (1 - P) = I * P + S * P + I - I * P - S + S * P, = I - S + 2 * S * P$. Then: $E_2 - E_1 = (I - S + 2 * SP) - (I - S + S * P) = S * P$.

Currently, Medicare only check from independent audit of the fees (such as inspection fees, medicines, etc.), to see whether it fits the basic medical insurance requirements or exceeds the highest proportion in the total costs which is the provision. However, it does not link them and not take the perspective of each case's treatment process to analyze the necessity and reasonableness of medical treatment. This shows that the Medicare found that the excesses of medical services and refuse of reimbursement of medical expenses is more difficult. Therefore, Medicare always tends to reimbursement of medical expenses for hospital, which is to say, the probability (P) that Medicare makes cooperate with the hospital is greater than zero. It is a very small chance or even does not exist that when P is equal to zero. No matter how much the probability that health care choose to cooperate with hospital, $E_2 - E_1$ is always greater than zero, which means the revenue when hospital chooses noncooperation was greater than choice of cooperation. Hence the hospital always choose noncooperation, and to hide medical information to Medicare. Specifically, it induces patients with excessive consumption of insured medical services and provides unnecessary tests and hospital services for insured patients. The insured patients are convinced by the medical services that provided by medical institutions, then they always receive the medical services that provided by medical institutions.

Through the above game, we find that in the case of asymmetric information, when Medicare pay for the project, the hospital's choice of noncooperation will achieve more earnings than choosing cooperation, and the Medicare has to undertake a huge amount of additional health care costs. That's why the medical costs is always very high.

4.4 The Game Analysis of Medicare and Hospitals Under Mixed Medicare Payment

In the "'12th five-year' deepening medical and health system planning cum" which is released in march 2012, China pointed out that: "reform and improve the Medicare payment system, increase reform efforts of Medicare payment, combined with the implementation of clinical pathways of disease and promote payment according to DRGs, capitation, the total amount of prepaid and so on in the whole country to enhance the effect of incentive that the Medicare do for medical behavior." The goal of exploration and reform of Medicare payment is to seek a balance point between the high quality and controlled costs of Medical services, which fully reflects the

Table 4.2 The game analysis model under the mixed mode of payment

Medicare hospital	Service project payment S_{11}	Total prepaid S_{12}
Reduce service S_{21}	I_{11} R_{11}	I_{12} R_{12}
Moderate service S_{22}	I_{21} R_{21}	I_{22} R_{22}
Increase service S_{23}	I_{31} R_{31}	I_{32} R_{32}

process of the game between payment of a fee and service providers. At present, it is still a short time after the implementation of health insurance reform in China, the knowledge of the social health insurance is not much and management tools and management measures are insufficient. Coupled with the large development gap between different regions, each region is difficult to find a comprehensive, reasonable and uniform method of payment in the medical insurance system reform, especially in the medical insurance payment. We think that the trend of the reform in health care payment system is the combination with prepaid and post-paid system to implement a mixed payment system. In general, the mixed payment system is better than a single mode of payment, and most payment methods can be used with other ways to eliminate the negative effects of a single approach while retaining the comprehensive advantages [1]. Below we will analysis the game between Medicare and hospitals under a mixed payment system combining with total prepaid and services paid.

The relationship between the choice of Medicare for the payment of cost and the number that hospitals provide for hospital services is a game relationship. The purpose of Medicare is to realize the maximization of its interests, whose game principles is to promote the hospital to provide moderation services for patients. Its alternative strategies include payment according to the total budget and the service project. The purpose of the hospital is to maximize its own interests; its game principle is to choose the number of medical services which can maximize its own interests. If taking the moderate service that Medicare hopes hospital to choose as a strategy of the hospital [12], then there are three kinds of alternative strategies of the hospital which are increase service, reduce service and moderate service.

Assuming that participant 1 equal to the medical insurance in the two sides game, its strategy showed as S_{1i}, $i = 1, 2$. S_{11} means that pay according to service projects; S_{12} means that pay according to the total budget. Participant 2 equal to hospital, its strategy showed as S_{2j}, $j = 1, 2, 3$. S_{21} means reducing service, S_{22} means moderate services, and S_{23} means increase service. The two strategies of health care and three strategies of hospital can be combined into six strategy combinations, for example, (S_{11}, S_{21}) is the strategy combination that Medicare choose pay according to diseases and hospital pay according to reduce service.

Assume that the benefits of hospitals and health care is I and R, under the strategy combination of (S_{11}, S_{21}), Medicare's benefits is showed with R_{11}, hospital's benefits showed with I_{11}, and so on, the benefits combination of health care and hospital can be used in Table 4.2.

We need to clear benefits size relations of Medicare and hospital under different combination strategies. According to the analysis of the benefits of health insurance, the size of the relationship that health care under the combination of six strategies is: (1) $R_{21} > R_{11}$ and $R_{21} > R_{31}$, (2) $R_{22} > R_{12}$ and $R_{22} > R_{32}$, (3) $R_{21} = R_{22}$.

We explain the size relationship of the R_{11} and R_{12}, R_{31} and R_{32} as follows. When take reducing service strategy in the hospital, the saved funding is in health care when paying according to the service items, otherwise, in the hands of the hospital when paying according to the total budget. As a result, $R_{11} > R_{12}$. When take increasing service strategy in the hospital, the additional fund of increasing service is paid by Medical, otherwise paid by hospital when paying according to the total budget, so $R_{32} > R_{31}$.

Based on the above argument, the size relationship of earnings that health care under the combined of six strategies is: (1) $R_{21} > R_{11} > R_{12}$ and $R_{22} > R_{32} > R_{31}$, (2) $R_{21} = R_{22}$.

According to the benefits analysis of the hospital, the size relationship of earnings that hospital under the combined of six strategies is: (1) $I_{31} > I_{21} > I_{11}$ and $I_{12} > I_{22} > I_{32}$, (2) $I_{21} = I_{22}$.

Assuming that health care selects strategy according to the probability distribution $P = (P_1, P_2)$. P_1 is the probability when health care choose strategy S_{11}, P_2 is the probability when health care choose strategy S_{12}. (P_1, P_2) is a mixed strategy of health care, $P_1 + P_2 = 1$. The purpose that Medicare select mixed strategy is to makes appropriate service strategy to be the dominant strategy of the hospital.

Assuming that the expected return is showed as E when health care adopt the mixed strategy $(P_1,\ P_2)$ and the hospital adopt pure strategy S_{2j} $(j = 1, 2, 3)$, then: When hospital take S_{21},

$$E_1(P, S_{21}) = P_1 I_{11} + P_2 I_{12}. \tag{4.1}$$

When hospital take S_{22},

$$E_2(P, S_{22}) = P_1 I_{21} + P_2 I_{22}. \tag{4.2}$$

When hospital take S_{23},

$$E_3(P, S_{23}) = P_1 I_{31} + P_2 I_{32}. \tag{4.3}$$

When hospital adopts S_{22}, the mixed strategy (P_1, P_2) of Health care should make the expected revenue greater than the hospital take the strategy of S_{21} or S_{23}, and then the following inequality is true:

$$\begin{cases} E_2(P, S_{22}) > E_1(P, S_{21}) \\ E_2(P, S_{22}) > E_3(P, S_{23}). \end{cases} \tag{4.4}$$

Plug Eqs. (4.1)–(4.3) into (4.4), we have:

$$\begin{cases} P_1 I_{21} + P_2 I_{22} > P_1 I_{11} + P_2 I_{12} \\ P_1 I_{21} + P_2 I_{22} > P_1 I_{31} + P_2 I_{32}. \end{cases} \tag{4.5}$$

According to $P_1 + P_2 = 1$ and $I_{21} = I_{22}$, we can get the solutions of the above inequality (4.5):

$$\begin{cases} P_1 > \frac{I_{12} - I_{22}}{I_{12} - I_{11}} \\ P_1 < \frac{I_{22} - I_{32}}{I_{31} - I_{32}}. \end{cases} \tag{4.6}$$

According to the knowledge of plane geometry and inequality, we can prove:

$$\frac{I_{22} - I_{32}}{I_{31} - I_{32}} > \frac{I_{12} - I_{22}}{I_{12} - I_{11}}. \tag{4.7}$$

So we can get the joint solution of inequality group is:

$$\frac{I_{12} - I_{22}}{I_{12} - I_{11}} < P_1 < \frac{I_{22} - I_{32}}{I_{31} - I_{32}}. \tag{4.8}$$

Then according to $P_1 + P_2 = 1$, we can get the solution of P_2 is:

$$\frac{I_{31} - I_{22}}{I_{31} - I_{32}} < P_2 < \frac{I_{22} - I_{11}}{I_{12} - I_{11}}. \tag{4.9}$$

Therefore, when health care choose mixed strategy (P_1, P_2) according to comply with the probability distribution (4.8) and (4.9), the expected revenue that when hospital take S_{22} is greater than take S_{21} or S_{23}, S_{22} (i.e., moderate service) is the hospital's dominant strategy.

When the hospital take S_{22}, the expected return when health care adopt mixed strategy P is as follows: $E(P, S_{22}) = P_1 R_{21} + P_2 R_{22} = R_{21}$. (Because $P_1 + P_2 = 1$, $R_{22} = R_{21}$) Health care realizes the maximization of the expected return, the mixed strategy (P_1, P_2) is Medicare's dominant strategy.

In conclusion, we have: when health care select mixed strategy P to comply with the probability distribution of (4.8) and (4.9), namely when choose mixed mode of payment, the hospital's dominant strategy is S_{22} which is appropriate services. (P, S_{22}) is the Nash equilibrium [3] of the mixed strategy game, when it is equilibrium, health care and hospital are all realizing the expected return maximization, the Nash equilibrium of the mixed strategy game just realizes Pareto optimal [8] of resources configuration.

4.5 Conclusion

Medicare payment is a system of mixed payment, and in terms of general situation, is superior to the single way. Through the innovation of payment, Medicare develops a reasonable means of payment for the incentive mechanism of provider. It has a positive significance to guide the medical behavior standard, improve the service quality and efficiency, promote the hospital to strengthen the construction of connotation and self management, and promote the reform of the internal operation mechanism. Of course, the reform of payment required health sector to transform the mode of management, improve the ability of management. The implementation of the mixed mode of payment makes a higher request to the ability of the management and needs to make a more rigorous scientific assessment and evaluation for medical service. Such as the practice of prepaid system needs to develop a scientific and rational medical quality evaluation system to evaluate the medical costs, the quality, the management of hospital and other aspects. This may be the only way to control costs at the same time to ensure the medical quality and service level.

Acknowledgments The National Natural Science Foundation of China: 71131006, 71172197.

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Chapter 5
Incorporation of EU Harmonized Classifications to Enhance Traditional Methods of Risk Analysis

Rute Ferreira, Elsa Boto and Celeste Jacinto

Abstract This paper describes a risk assessment (RA) study focusing on the circumstances of occupational accidents in a Portuguese company of the "hotel, restaurant and catering" sector (HORECA). The aim was to modernize current practice by incorporating new features into traditional RA techniques; this new development gave particular attention to the integration of harmonized variables established by the Eurostat within the European Statistics on Accidents at Work (ESAW) classification system. The study consisted of two parts and it used a number of harmonized variables: (1) the characterization of the company's "typical accident", defined here as the most frequent type of accident (2011–2012 period), and (2) the analysis (and assessment) of occupational risks using the new procedure, i.e., the "enhanced methodology". In the latter case, the idea was to run a trial test of the procedure's application and usefulness, especially in terms of its ability to provide a clearer identification of "accident scenarios". The results allowed mapping the relevant risk situations, in which "falls on the floor" are the prevalent type of accident (contact); this accident mode is associated with two categories of physical activity: carrying by hand/transporting a load, or ordinary movements (e.g.: walking, running, going up, going down, etc.). The most frequent injuries are dislocations, sprains and strains, or wounds and superficial injuries. The conclusions highlight the advantages of using European harmonized classifications with any kind of risk assessment methodology. This improved procedure is likely to produce comparable information (outputs), which can embrace both accidents at work and/or occupational diseases.

Keywords ESAW · Hazard · Risk · Occupational accident · Occupational disease

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_5,

5.1 Introduction

Employers have the legal duty to guarantee low-risk workplaces and to prevent the occurrence of occupational accidents and diseases. This also means that the discussion on workplace risk assessment is far from being "old news". On the contrary, companies are compelled by many (e.g.: Unions, Governmental Agencies and the Society in general), to go further in their efforts to advance good practice in this domain. The present work describes one of such attempts to update and improve procedures for dealing with both accident analysis and risk assessment.

This Risk Assessment (RA) study has taken place at *Instituto Técnico de Alimentação Humana* (ITAU), in English "Technical Institute of Food". The core business of ITAU is focused on high quality food services, including both production of meals and catering, distributed by schools, hospitals, and other companies. It was established in 1963 and belongs to the Portuguese "hotel, restaurant and catering" sector (HORECA).

The objective of this work was to improve and update the RA methodology currently used by ITAU; the underlying idea was to create a harmonized database and be able to compare the results with European statistics. This new development, therefore, includes European harmonised classification schemes established by the Eurostat for both accidents at work and occupational diseases [5, 8]. The updated and improved approach was subjected to a "pilot test" application, in a hospital kitchen run by ITAU.

This enhanced RA methodology has a more structured basis and it facilitates not only the use of a "common language" for risk communication, but also the creation of a specific "occupational hazards map", structured by occupation. The ultimate goal is to improve current practice and to reinforce the implementation of ITAU's Occupational Safety and Health (OSH) management system.

5.2 Background

Terms like hazard and risk have been used since ever, but they can have different meanings depending on the situation and context. These two terms must be well defined when used in OSH studies, so within this work, the authors have adopted the OHSAS 18001:2007 definitions. A hazard is defined as *source, situation, or act with a potential for harm in terms of human injury or ill health, or a combination of these*; on the other hand a risk is defined in this standard as *combination of the likelihood of an occurrence of a hazardous event or exposure(s) and the severity of injury or ill health that can be caused by the event or exposure(s)* (in OHSAS 18001:2007).

Two other important terms in OSH nomenclature are incident and accident. Over the years several authors have been proposing their own definition for accident. According to Hollnagel [11] an accident can be defined *as a short, sudden, and unexpected event or occurrence that results in an unwanted and undesirable outcome* [11].

Furthermore, Harms-Ringdahl [10] defines accident as *an event that causes damage or injury, but which was not intended to have a negative outcome* [10]. However, the OHSAS 18001 standard definition of an accident is a sub-category of incident, as follows: *an incident which has given rise to injury, ill health or fatality*.

To answer the need for assessment and correction of systems weaknesses a set of tools have been developed over the years by experts. Overall, risk assessment methodologies include three main phases, one phase of hazard identification, other of risk evaluation, and finally a phase to establish risk control measures, which are subjected to hierarchy. One possible definition cited by Marhavilas et al. [15] states that risk assessment is an essential and systematic process for assessing the impact, occurrence and the consequences of human activities on systems with hazardous characteristics [15]. Risk assessment should be revised whenever needed to improve good practice and assist OSH management in companies.

Among the newest developments related to risk assessment in industry, one can find studies focusing on the assessment of risk factors concerning "new product development" (NPD); examples are, for instance, recent work by Choi and Choi [4] and Choi et al. [3]. However, it should be stressed that, not only such new approaches follow the same RA general principles, but also, and perhaps most importantly, new products and new technologies can also bring new (emergent) occupational hazards.

Within the OSH context, risk assessment should embrace both accidents at work and occupational diseases. The European Regulation (EC) No 1338/2008 defines occupational disease as *a case recognized by the national authorities responsible for recognition of occupational diseases. The data shall be collected for incident occupational diseases and deaths due to occupation*; it should not be mistaken for work-related health problems and illnesses. According to the same European source, work-related health problems and illnesses *are those health problems and illnesses which can be caused, worsened or jointly caused by working conditions. This includes physical and psychosocial health problems. A case of work-related health problem and illness does not necessarily refer to recognition by an authority and the related data shall be collected from existing population surveys such as the European Health Interview Survey (EHIS) or other surveys* (EU Regulation 1338/2008).

Sometimes, historic accident data tend to be used by companies as a way of "measuring" risk with "blind" numbers or statistics. According to Aven [1], however, these numbers do not express risk, but rather provide a basis for doing it. Additionally, this historic data can help understanding the accident phenomena and provide very useful inputs for risk assessment.

There are many RA methodologies; they can be classified, broadly, as qualitative, quantitative (usually probabilistic) and semi-quantitative techniques. However Harms-Ringdahl introduces a different approach categorising RA methods according to its principal aim.

The OSH matters are among the most important areas where the European Union (EU) social policies are centered. A good example to attest the importance of OSH issues at EU level is the work developed by Eurostat [8] concerning the European Statistics on Accidents at Work (ESAW) classification system. This project had three developing phases: Phases I and II covered a set of 14 "classical" variables, which included variables that already existed in most EU countries' data bases. On the other hand, phase III has introduced 8 new variables and, since 2001, it marked the beginning of a new statistical series [8, 13] across the EU. In Portugal, 6 of the new variables are implemented in the Portuguese official system [14].

5.3 Methodology

This work's intention is to modernize current practices by incorporating new features into traditional RA techniques. It is important to emphasize that this work is not about the risk assessment methodology itself, but, as afore mentioned it gives particular attention to the integration of harmonized variables established by ESAW system and to understand how they can contribute to RA. The study is structured into five methodological steps: (1) re-classification of previous accidents' data, (2) characterization of the "typical accident" of ITAU, (3) modernization of ITAU's risk assessment tool, (4) running a RA pilot study at ITAU's unity and (5) drawing conclusions.

This work began with the re-classification of accidents' data collected in the years 2011 and 2012, within the hospital segment of ITAU business. The ESAW variables used in this study were: sex and age, nationality, specific physical activity, deviation, contact, material agent associated to contact, type of injury and body part injured. The name of some of these variables is self explanatory, i.e., it is possible to understand what they mean just by its name (e.g.: age or sex). However, a few others need to be defined to warrant a better understanding of its application, as follows [8]:

- Specific Physical Activity—this is the activity being performed by the victim just before the accident, i.e. precisely what the victim was doing at the exact time,
- Deviation—this is the last event deviating from normality and leading to the accident, i.e. the Deviation is the event that triggers the accident,
- Contact Mode of Injury—it is the contact that injured the victim, i.e. it describes how the person was hurt (physical or mental trauma),
- Material Agent of Contact—it is the main Material Agent associated with, or linked to the injuring contact.

During the study period (2011–2012) there were 50 accident records in the hospital segment of this company. Their re-classification with the new variables (Step 1) was important for the characterization of the "typical accident", which resulted from descriptive statistics; such statistics allowed comparison with HORECA's European and Portuguese data. In this work, the "typical accident" is defined as the markedly most frequent modality of accident and its causation mechanism.

The enhanced RA approach proposed here was built by integrating several methodologies, such as the traditional Job Safety Analysis (JSA), the BS 8800:2004 Risk Matrix, some ESAW variables, and the classification of European Occupational Disease Statistics (EODS).

The JSA methodology constituted the main pillar, and the adequacy of its application to a kitchen had already been demonstrated by Harms-Ringdahl in 2013 [10]. Moreover, this method was chosen for being useful in work situations involving manual tasks. This is a method of direct analysis of hazards through the scrutiny of tasks and procedures performed by a person or group of people, focused directly on the injury or damage that may occur. JSA involves four main phases: (1) structuring and planning, (2) identifying hazards, (3) evaluating risks, and (4) proposing risk control measures [10].

The JSA method does not provide any specific tool for assessing risk level. So, this approach has incorporated the risk matrix proposed by the British Standard BS-8800:2004. This evaluation tool was chosen to match the spirit of pushing the ITAU's current practice towards standardisation. The matrix has 5 risk levels, based on a (3×4) combination: 3 severity levels and 4 likelihood levels. The three intermediated risk levels (Low risk, Medium and High risk) constitute the so-called ALARP zone, in which risks should be lowered to a level "As Low As Reasonably Practicable".

To establish risk control measures (or improvements), the guidelines of BS8800: 2004 were followed. Such guidance establishes a hierarchy of controls, which should be applied in the following order: engineering measures, organizational measures, protective measures (collective or individual) and emergency/contingency arrangements [2].

The ESAW methodology was incorporated in this new RA procedure to describe accident scenarios associated with hazardous situations. At this point the variables used were: contact, type of injury, and part of body injured; together, these three variables portray the accident scenario.

At last, the identification/classification of occupational diseases was made through the EU methodology known as EODS [5]. Its aim is to obtain gradually harmonised, comparable and reliable data and indicators on occupational diseases in Europe [5]. This method not only describes occupational diseases, but also, just like the ESAW system, it includes a structured coding for each "type of disease".

5.4 Results and Discussion of Application

1. Case study

The piloting test of this integrated methodology ran in a hospital kitchen that belongs to ITAU's hospital segment; this particular segment or business area, as a whole, covers around 20 units, i.e., hospital canteens and/or kitchens.

Due to implementation of "food safety" regulations, namely the Hazard Analysis and Critical Control Points (HACCP), the facilities of the specific unit studied (code 1616779) underwent renovations in 1988, when the whole floor was replaced and specific processes were physically separated by areas to avoid cross-contamination. This kitchen is divided into the following main areas, corresponding to specific processes:

- One large reception and storage area (including different types of storage facilities),
- Four preparation areas (for fruit, vegetables, meat and fish; preparation activities include the use of many hand-tools, some of which are motorised),
- Three kitchens (for milk products, diets and general meals; activities in these kitchens include all sorts of cooking tasks and use of many apparatus),
- One area for desserts (includes preparation and cooking),
- One area for placing meals in trolleys for distribution to hospital patients,
- Two washing and desinfection areas (for thick crockery and fine China).

When the study took place there were 46 workers on this ITAU's unit, all women. The workers were distributed by professions as follows: the commissioner, the sub-commissioner, three pantry women, four cooks, eight kitchen assistants and seven canteen workers, four tapsters (bar tenders) and 18 workers for customized deliveries. Although these workers perform tasks essentially related to the profession, sometimes they have to either help or replace others and, therefore, can also be exposed to other risks, uncommon to their specific profession.

The present study covered both safety risks (accidents) and health risks (diseases) for all tasks and professions, from the reception of raw materials to the washing up areas, as well as the delivery of finished meals to the hospital wards. In total more than 100 hazards were assessed in this hospital kitchen.

Tasks that involve cleaning the facilities (i.e., general washing and disinfections) can interfere with other tasks, since they can be carried out simultaneously. The same might happen with certain maintenance activities. As a principle, the two mentioned processes (general cleaning and maintenance) should be scheduled for different periods; however the workers tend to perform such tasks whenever it seems more suitable to them, which means that sometimes these may occur simultaneously with the "normal" production activities.

2. Characterization of the "typical accident"

The opportunity to characterise the "typical accident" arose from the observation that ITAU does not follow a standard classification of accidents. Until now, any report or study prepared with the aim of analysing accidents served only as a basis for internal comparisons over the years (i.e., to identify trends) and it could not be used to compare data with competitors or with national/ European accident statistics.

With the re-classification of accidents through the 2011–2012 biennium, using the ESAW classification, these newly coded data provided a starting point for identifying specific hazards and the "typical accident" of ITAU hospital segment (all units of this segment).

The adoption of the variables used by ESAW is a potentially important contribution to the effort of prevention, as far as they allow to characterize and give a better understanding of the modality of accident (characterised by the variable Contact), the Material Agent involved on it and its immediate cause (characterised by the variable Deviation).

The data used in this study covers 50 accidents ($n = 20$ in 2011 and $n = 30$ in 2012). In the period under consideration (2011–2012), 646 and 696 persons were working in the whole hospital segment, respectively. From Table 5.1, one can observe

Table 5.1 Indicators of relevance (all units of the hospital segment)

	2011	2012	Annual average
N^o fatal accidents	0	0	0
N^o non-fatal accidents	20	30	25
Days lost	230	612	421
Average severity (average days/accident)	11.5	20.4	15.95
Incidence per 100,000 *workers*	3,095.9	4,310.3	3,703.12

that there were no fatal accidents, which is not surprising in ITAU. However, in the case of non-fatal occurrences, all indicators show a significantly worse scenario from 2011 to 2012. Not only has the number of accidents increased, but also their severity, i.e., more days lost per accident, on average. Based solely on the data from this biennium, there is no logical explanation for such increase. On the other hand, OSH data of 2010 and before was out of reach for the present study, since it was already stored in the company's historical archives. In any case, this simple fact suggests the need for more in-depth analysis, as well as more detailed risk analysis.

The incidence rates in the years 2011 and 2012 were, respectively, 3,095.9 and 4,310.3 accidents per 100,000 workers. Comparing the incidence rate of 1 year alone has little meaning; therefore, the average was calculated, and the table shows that the resulting annual value (~3,700) is slightly above the EU average of HORECA's sector (~3,041) [7]. Once again, this result shows that there is room for improvement and also that more specific analysis are recommended in this company. With respect to the "typical accident", its characterisation was based on the same re-coded data and using the 9 variables referred in Sect. 5.3 (methodology). Table 5.2 gives the most frequent category (or modality) for each variable used in this study. Since the typical accident is defined through the markedly most frequent modality of these key variables, the results provided in Table 5.2 allow describing the "typical accident" at ITAU's hospital segment.

Thus, in the study period the "typical accident" in this segment can be roughly described as the occurrence that happened to a woman—cod. 1 (89 %), with Portuguese nationality—cod. 1 (77 %) in the age group of 45–54 years (31%) or 25–34 years (29 %). The accident happened when the worker was carrying something by hand—cód.50 (37 %) or was moving herself to somewhere—cod. 60 (33 %). This resulted in the fall of the worker—cod. 030 (39 %) against the floor—cod. 01.00 (36 %), likely caused by slipping/stumbling—cod. 50 (37 %). This occurrence may cause dislocations, sprains or strains—cod. 030 (43 %), or wounds and superficial injuries—cod. 010 (39 %), in which the upper extremities—cod. 50 (54 %) were the most frequently affected.

However, there are two other deviations that also called for attention in this study, they are: body movement without any physical stress—cod. 60 (22 %) and loss of control of handling equipment—cod. 40 (18 %). So, a partial conclusion related to the deviation variable, i.e., direct cause, is the fact that the most frequent "top-3" (i.e., codes 50, 60, 40) are all of human nature (i.e., each embodies erroneous

Table 5.2 Variables relevant for characterising the "typical accident"—hospital segment (2011–2012)

	Description	2011 (%)	2012 (%)	Average (%)
Sex	Woman (cod. 1)	85	93	89
Nationality	Portuguese (cod. 1)	70	83	77
Age	25–34 years	25	33	39
	45–54 years	15	47	31
Specific physical activity	Carrying by hand (cod. 50)	40	33	37
	Movement (walking, running) (cod. 60)	30	37	33
Deviation	Slipping—stumbling and falling-fall of persons (cod.50.)	30	43	37
Contact-mode of injury	Horizontal or vertical impact with or against a stationary object (the victim is in motion)-result from a fall (cod. 30)	35	43	39
Material agent of contact	Buildings—at ground level (floor) (cod. 01.00)	25	47	37
Type of injury	Dislocations, sprains and strains (cod. 030)	35	50	43
	Wounds and superficial injuries (cod. 010)	35	43	39
Part of the body injured	Upper extremities (cod. 50)	48	60	54

human actions). Although the timeframe (2 years) in this study is short, this indicates a need for improving safe behaviour and working procedures.

The workers in this segment are more likely to be injured by accidents caused by slips, trips and falls, especially in kitchen areas. According to EU-OSHAS [6], the majority of "slip" injuries happen on wet floors, while most "trips" are due to poor cleaning, which were also observed as problems in this case, corroborating previous knowledge [7].

Additionally, this study results were also compared with the national Portuguese statistical scenario, using the official report on "accidents at work" (with 2010 accident data), produced by the Office of Strategy and Planning of Portuguese Government [9]. This official report uses ESAW harmonised variables; using the same approach as above, from the frequency distribution of these variables, one can also pick the typical accident within the HORECA Portuguese sector in 2010 as follows: What happened to a man, aged between 25–34 years, who was in movement (physical activity cod. 60). This occurred when he lost control (total or partial) of machine, means of transport or handling equipment, hand-held tool, object, or animal (deviation cod. 40). Such deviation could cause horizontal or vertical impact with or against a stationary object (the victim is in motion) (contact cod. 30) or contact with sharp, pointed, rough, coarse agent (contact cod. 50). The injuries would be wounds and superficial injuries (cod. 10) or dislocations, sprains and strains (cod. 30). There were two parts of the body most likely injured: lower extremities (cod. 60), and upper extremities (cod. 50) [9].

The above characterisation shows certain similarities with the findings in ITAU's hospital segment, such as, age range, physical activity, one of the relevant deviations, contact, types of injury (both of them), and one category of part of the body. However, there are also a few relevant differences, namely the sex of the victim and the existence of a second category of contact (in this case the contact with sharp, pointed objects). Despite a considerable overlapping in the most frequent type of accident, one needs to be careful in drawing conclusions, considering that the HORECA sector is very broad and it also includes other business (e.g.: restaurants and hotels).

3. Risk Assessment—Pilot Application

As mentioned, the application of the improved RA procedure was carried out in one single kitchen. After a few observation visits and a detailed analysis of the working processes in this unit, it was possible to (re)design a risk assessment procedure, taking into account the JSA general methodology, together with the BS 8800 Risk Matrix, as well as the ESAW [8] and EDOS [5] classification systems.

Once the hazards had been identified for each task, the occupational risks were characterised through the ESAW and EODS classifications. This allowed the harmonised coding of relevant accident scenarios (safety risks), as well as the diseases likely to develop within the medium/long term (health risks). Whenever several risks were identified simultaneously, the risk level was scored considering the worst scenario (either the most probable or the most severe).

Although the tasks within the unit are diverse, many risks are common to several activities, despite the risk level being different from one task to another. Figure 5.1 is a small extract from the whole analysis, only to illustrate this procedure. Tasks involving "handling/transportation", for example, are those which have a higher level of risk, as illustrated in Fig. 5.1. By contrast, tasks involving contact with cold environments have a very low level of risk, which is due to the fact that the contact time is usually short and that it is almost always done with proper equipment (gloves and insulated clothing).

From the whole analysis it stands out that the four most frequent (and also higher risk) accident scenarios were: (1) physical stress on the musculo-skeletal system; (2)

Risk Assessment: Unit 1616779 ITAU (hospital kitchen)											
Risk Analyses					Risk Assessment						Recommendations
Activity	**Task/ Process**	**Hazard/ Hazardous situation (deviation)**	**Risk of accident (ESAW): Contact; Type of injury; Part f the body injured**	**Risk of disease/ EODS classification**	**Possibility**	**Severity**	**Risk level**	**Acceptable**	**ALARP**	**Unacceptable**	**Proposed Control Actions**
Preparation	Preparation of vegetables and fruits	Incorrect handling of cutting tools (eg: knives, manual grater)	• Contact with sharp Material Agent (cod. 51); Open wounds (cod. 12); Upper Extremities (cod. 50) • Struck - by falling object (cod. 42); Superficial injuries (cod. 11); Lower Extremities (cod. 60), Upper Extremities (cod. 50)	• Carpal tunnel syndrome (cod. G560); arthrosis on the wrists (cod.931) and other diseases related with the use of hand tools	2	2	**Medium**		yes		✓ Ensure the existence of a local storage area for tools ✓ Use only appropriate cutting tools (eg: knives, grater) ✓ Rotation of workers ✓ Make frequent breaks between the various tasks ✓ Training of workers: attitudes / work instructions (safe work) ✓ Use proper protection: footwear and gloves (PPE)
Cooking	Cooking meals	Transporting food, kitchenware, and heavy loads	• Physical stress - on the musculo-skeletal system (cód.71); Dislocations, sprains and strains (cod. 30); Back, including spine and vertebra in the back (cod. 30), Upper Extremities (cod. 50) • Vertical motion, crash on or against (resulting from a fall) (cod. 31); Dislocations, sprains and strains (cod. 30), Bone Fractures (cod. 20), Wounds and superficial injuries (cod. 10); Lower Extremities (cod. 60), Upper Extremities (cod. 50)	• Musculo-skeletal diseases - with permanent disabling effects (e.g.: low back pain)	3	2	**High**		yes		✓ Maintenance of the floor (anti-slippery surface treatment) ✓ Ensure that transportation is made, whenever possible, in transport cars ✓ Rotation of workers ✓ Training of workers: attitudes / work instructions (safe work) ✓ Use proper protection: footwear and gloves (PPE)
		Direct contact with hot surfaces, hot containers, or contact with stoves	• Contact with naked flame or a hot or burning object or environment (cód.13); Burns, scalds (thermal) (cod. 61); Upper Extremities (cod. 50)	*Not applicable*	3	2	**High**		yes		✓ Proper maintenance of stoves, ovens and all kitchen equipment ✓ Reduce time of exposure to risk ✓ Training of workers: attitudes / work instructions (safe work) ✓ Use proper protection: footwear and gloves (PPE)
General		Physical or psychological aggression from clients (especially in Canteens)	• Bite, kick, etc. (animal or human) (cod. 80); Superficial injuries (cod. 11); Shocks after aggression and threats (cod. 111)	• Fatigue • Psychological stress • Depression	3	1	**Low**		yes		✓ Perform advance planning of the tasks ✓ Training of workers
		Poor lighting for tasks performed	*Not applicable*	• Loss of visual accuracy	1	2	**Very low**	yes			✓ Planning maintenance of lighting and ensure compliance with the plan ✓ Make frequent breaks between the various tasks

Fig. 5.1 Illustration of a part of the risk assessment (exert of the whole analysis document)

vertical motion, crash on, or against (resulting from a fall); (3) struck by object in motion or collision with; (4) contact with naked flame or a hot or burning object. Of these, three categories are visible in Fig. 5.1.

It appears that the first two scenarios above mentioned are associated with body movement and/or manual transport of loads; consequently, in these cases there is also a higher likelihood that workers will suffer from occupational diseases related to musculo-skeletal disorders (MSD), such as, for instance, low back pain or tendonitis. The most common types of injuries are: (1) wounds and superficial injuries, and (2) dislocations, sprains and strains; bone fractures are also considered quite possible outcomes. Body parts most affected are the upper and lower extremities.

These RA findings are in agreement with the “typical accident” occurred in 2011–2012, i.e., “crash against the floor, which is probably caused by slips/falls, while the worker is carrying by hand or moving”. Naturally, this RA reveals several other accident risks to which workers are exposed to, despite these others not being part of the specific “typical accident”.

One of such cases is the high risk of contact with naked flame or a hot or burning object [c.f. scenario (4)]. The hazardous situation related to this modality of accident is in fact very common in any kitchen. The control actions proposed in this case (see Fig. 5.1) are to ensure transportation, whenever possible, on transport cars, rotation of workers, reinforcement of training concerning attitudes, safe work instructions and the use of proper protection gloves. In a kitchen, the incorrect handling of cutting tools is a common hazard leading to contact with sharp, pointed, coarse materials or tools (contact cod. 50). This modality of accident was highlighted in the Portuguese HORECA sector, but in this particular kitchen it was classified as medium risk.

In what concerns occupational health in this workplace, musculo-skeletal disorders (MSD) appear to be the most common risks; however problems related to hearing loss are also an issue, especially in the washing areas for thick crockery and fine China. Skin diseases, such as leptospirosis, caused by infection with *Leptospira bacteria*, or dermatophytes caused by fungus, can become a problem too; however, they will not be severe cases but can cause discomfort.

Finally, when comparing these new results with those of previous assessments, it became obvious that there were significant improvements: not only the standard terminology allowed comparisons, but also the final output was more detailed in terms of risk characterisation and coverage.

5.5 Conclusions

The improved risk assessment procedure applied in this hospital kitchen revealed four kinds of hazardous situations that need careful consideration from the OSH management of ITAU. These are the movement of people (e.g.: walking on slippery floors), the transport by hand, the incorrect handling of cutting tools and contact with flame/hot or burning object or environment.

This study fulfilled the objective of modernising and updating the risk assessment tool used previously by the company.

However the implementation of this enhanced procedure may face some obstacles, since it implies that all safety professionals of ITAU receive some training on the use of these harmonised classifications; in addition, the analysis requires more time than before. However, such effort is seen as good investment, since it brings tangible benefits.

This work demonstrates that the integration of harmonised classifications allows comparisons of data and statistics, at national and European level, which were impossible before. In addition, it represents a step ahead in terms of good practice. Furthermore, the adoption of these harmonised classifications allow to improve risk communication and the whole cycle of information in general, because the common language builds a bridge between risk assessment and accident analysis, thus, facilitating the management process.

At last, it must be highlighted that the above mentioned benefits are not restricted to the EU countries, since most of these harmonised variables and their respective terminology are also a recommendation of the International Labour Organisation (ILO) since 1998 [12], thus, any steps in this direction could have international application.

Acknowledgments The authors would like to thank ITAU's management and workers for allowing this study and for their participatory involvement.

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Chapter 6
A Bilevel Programming Model for an Agriculture Production-Distribution System with Fuzzy Random Parameters

Zhimiao Tao and Xiaoye Qian

Abstract In this paper, we focus on a production-distribution system consists of a producer and a distribution center. We formulate a bilevel multiobjective programming model for it. The upper model is to maximize the producer's profit and the lower model is to maximize both the distribution center's profit and customers' satisfaction degree. Some decision parameters, including unit production cost, customers' demand and unit sale price, are assumed as fuzzy random variables due to complex decision environment. Chance-constrained technique are used to tackle the uncertainty of this model. A modified genetic algorithm is be used to solve the problem. A numerical example illustrates the effectiveness and efficiency of the model and the algorithm.

Keywords Bilevel multiobjective programming · Production-distribution problem · Fuzzy random variable · Genetic algorithm

6.1 Introduction

Production-distribution system is a key issue in ensuring the effectiveness of whole supply chain. The problems of designing production-distribution systems have attracted a lot of researchers [1, 4, 16].

Most of models presented hitherto assume that there is only one decision maker, that is, the production section and distribution section belong to a principal firm, in the production-distribution system, However, in real production-distribution system, the production section and distribution section are distinct and they are non-cooperative for their own benefits. For instance, in a agricultural products supply chain, farmers

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_6,

provide agricultural products to distribution center, and the distribution center sell agricultural products to customers. Both the farmers and the distribution center optimize their objectives respectively. Obviously, their benefits are not completely consistent. Farmers hope sell their product with a good price but distribution center tend to purchase cheaper products to reduce its cost. Classical single level programming models are not appropriate for the situation. It is more likely to be formulated by using bilevel programming model.

A bilevel programming model is a programming model in which a subset of the variables is required to be an optimal solution of a second mathematical programming problem. Bilevel programming models are effective tools to tackle hierarchical structures, which widely exist in many real complex programming problems. Since its rich contents and wide application, bilevel programming is studied by researcher from various aspects [2, 6, 8, 13, 15].

In a production-distribution problem, some parameters, such as demand, can be describe as a fuzzy variable based on the decision maker's experience and judgement. However, it is not easy to estimate the most possible value exactly. Nevertheless, we can obtain the distribution of the most possible value on the basis of statistics characteristics of the market. So it is reasonable to defined these parameters as fuzzy random variables. The concept of fuzzy random variable was introduced by Kwakernaak [9, 10] to study randomness and fuzziness at the same time. Later on, some variants and extensions were developed by other researchers for different purposes; see for example, Puri and Ralescu [14], López-Diaz and Gil [11], Luhandjula [12], and Gil [7].

The remainder of this paper is organized as follows: Sect. 6.2 states the bilevel decision structure and the motivation of using fuzzy random variables. In Sect. 6.3, we formulate a bilevel multiobjective programming model with fuzzy random parameters for the production-distribution center. Comprehensive explanation of the proposed st-GA is given in Sect. 6.4. Section 6.5 provides an application example to illustrate the performance of the st-GA using actual data obtained from a company in China. The efficacy and the efficiency of this method are demonstrated by comparing its numerical experiment results with those of tradition matrix-based genetic algorithm in Sect. 6.5. Finally, concluding remarks are outlined in Sect. 6.6.

6.2 Key Problem Statement

The problem considered in this paper is a decision on a production-distribution system. The general characteristics of the system is bilevel multiobjective decision structure and fuzzy random decision environment, which are stated as follows.

6.2.1 Bilevel Multiobjective Decision Structure

Consider the production-distribution system of a kind of well-sold produce. A farmer yields the raw produce and the distribution center is responsible for purchasing,

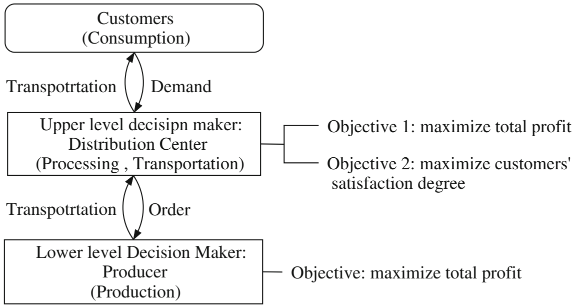


Fig. 6.1 Decision structure

holding, processing the raw produce and transporting and selling the finished products. The interests of the producer and the distribution center are not the same. The producer wants two sell the produce with a good price, but the distribution center hopes to purchase raw produce with a lower price to reduce its cost. So it is unsuitable for modelling the production-distribution system problem with only one decision maker. It is more likely to be modeled by using bilevel programming, which has been proposed in the literature as an appropriate model for hierarchical decision processes with two different decision makes, the leader at the upper level of the hierarchy and the follower at the lower level. For the problem considered in this study, the distribution center is an agricultural industrialization leading enterprise. It controls the producer's decision by setting the purchasing price and order quantity. The producer determine output according to purchasing price and order quantity. The output affects the production centers' adversely. So the leader of the hierarchical production-distribution system is the distribution company and the follower is the farmer.

As to objectives, the discretion center aims to maximize its profit and minimize transportation time. The follower, on receiving the purchasing price and order quantity, decides the output seeking to maximize his profit. As mention above, the production-distribution system can be formulated by a bilevel multiobjective programming model illustrated by Fig. 6.1.

6.2.2 *Fuzzy Random Decision Environment*

The need to address uncertainty in production-distribution is widely recognized because uncertainties exist in a variety of system parameters. As a result, the inherent complexity and stochastic uncertainty existing in real-world water resources decision-making have essentially placed them beyond conventional deterministic optimization methods.

Take the customers' demand as an instance, many studies assumed demand as deterministic for simplifying models. However, demand is influenced by both natural and socials factors. So the demand tends to fluctuate. It is difficult for the decision maker to give a crisp description for this parameter, but he can depict the demand as a fuzzy variable based on his experience and judgement. In this study, a fuzzy variable is assumed as be triangular, i.e., (a, ρ, b). On the basis of statistics characteristics of the market, it is found that the most possible value of demand approximately follows a normal distribution, i.e., $\rho \sim \mathcal{N}(\mu, \sigma^2)$. In this situation, a fuzzy random variable is applied to depict the demand which combined fuzziness and randomness

6.3 Model Formulation

In this section, the some relevant assumptions and notations are outlined. Then a brief introduction of fuzzy random variable is presented. After that, a bilevel multiobjective programming model for the production-transportation system is formulated.
Assumptions

1. Inventory is not considered.
2. All the raw materials are processed.
3. The price is inversely proportional to the demand.
4. Demands, transportation time from distribution center to customers are fuzzy random variables.
5. The distribution center undertakes all the transport task.
6. All the produce from the agricultural base is purchased by the distribution center.
7. The unit production cost inversely proportional to the square root of the output.

Notations

K potential number of vehicles in the distribution center, indexed by k,
J potential number of customers, indexed by j,
$\tilde{\bar{p}}_j$ the unit price to customer i,
θ_{kj} loss rate of transportation from the distribution center to customer j by vehicle k,
y the purchasing quantity,
v_k the unit transportation cost from the production base to the distribution center by vehicle k,
w_k the fixed transportation from the production base to the distribution center by vehicle k,
v_{jk} the unit transportation cost from the distribution center to customer j by vehicle k,
w_{jk} the fixed transportation from the distribution center to customer j by vehicle k,
b the unit proceeding cost in the distribution center,
ϑ the processing loss rate,
C the processing capacity of the distribution center,
$\tilde{\bar{h}}_{jk}$ transportation time from the distribution center to customer j by vehicle k,
T_j the aspired time of customer j for the product,
p' the unit production cost for production center,
Y the production capacity of the agricultural base,
t_k the transportation capacity of vehicle k,
x_{jk} the transportation quantity from the distribution center to customer j by vehicle k,

- x the unit purchasing price,
- x_k the transportation quantity from the agricultural base to the distribution center by vehicle k,
- y the agricultural base's output.

6.3.1 Bilevel Model Formulation

We formulate upper level model for the distribution center and lower level model for the farmer. By integrating the lower level model into the upper level model, we formulate the global model for the production-distribution system.

6.3.1.1 Upper Level Model

The distribution center is an agricultural industrialization enterprise. A brand products of the distribution center is popular with customers. The brand products are made from the materials from the agricultural base. The distribution center is the leader of the production-distribution system, and influence the agricultural base's decision by determining purchasing price.

For the distribution center, the profit function is formulated by:

$$\begin{aligned}\tilde{\bar{F}}_1 &= \sum_{j=1}^{J} \tilde{\bar{p}}_j \sum_{k=1}^{K} (1-\theta_{jk})x_{jk} - xy - \sum_{k=1}^{K}(x_k v_k + \eta(x_k)w_k) \\ &\quad - \sum_{j=1}^{J}\sum_{k=1}^{K}(x_{jk}v_{jk} + \eta(x_{jk})w_{jk}) - b\vartheta \sum_{k=1}^{K} x_k,\end{aligned} \tag{6.1}$$

where the first item represents the sales revenue, the second item is the purchasing cost, the third and the fourth items compose the transportation cost, and the last item is the processing cost. $\eta(x_k)$ takes values of 1 if x_k is positive, i.e., vehicle k is used; otherwise $\eta(x_k)$ is 0. $\eta(x_{jk})$ has the same meaning. It follows from assumption 3 that sale price p_j can be formulated by:

$$\tilde{\bar{p}}_j = \frac{p_j^0}{\tilde{\bar{D}}_j}, \tag{6.2}$$

where p_j^0 are constants, $j = 1, 2, \cdots, J$. So (6.1) can be written as:

$$\begin{aligned}\tilde{\bar{F}}_1 &= \sum_{j=1}^{J} \frac{p_j^0}{\tilde{\bar{D}}_j} \sum_{k=1}^{K} (1-\theta_{jk})x_{jk} - xy - \sum_{k=1}^{K}(x_k v_k + \eta(x_k)w_k) \\ &\quad - \sum_{j=1}^{J}\sum_{k=1}^{K}(x_{jk}v_{jk} + \eta(x_{jk})w_{jk}) - b\vartheta \sum_{k=1}^{K} x_k.\end{aligned} \tag{6.3}$$

In a competitive market, customers' satisfaction degree plays an important role for a company's development in the long run. Assume the product is well-sold, the customers hope their demands are met as far as possible in a certain period. The customers' satisfaction degree is measured by the proportion of the actually received products in the whole demand, denoted by:

$$\tilde{\tilde{F}}_{2j} = \sum_{k=1}^{K}(1-\theta_{jk})x_{jk}/\tilde{\tilde{D}}_j, \quad j = 1, 2, \cdots, J. \tag{6.4}$$

By integrating the above objectives, the processing capacity constraint condition of the distribution center, the raw materials constraint condition and time constraints and apply the chance-constrained technique [5], the upper model is formulated as:

$$\begin{cases} \max\limits_{x, x_k, x_{jk}} \ \left[\overline{F}_1, \overline{F}_{21}, \overline{F}_{22}, \cdots, \overline{F}_{2J}\right] \\ \text{s.t.} \begin{cases} Ch\left\{\sum\limits_{j=1}^{J} \frac{p_j^0}{\tilde{\tilde{D}}_j} \sum\limits_{k=1}^{K}(1-\theta_{jk})x_{jk} - xy - \sum\limits_{k=1}^{K}(x_k\tilde{\tilde{v}}_k + \eta(x_k)w_k) \right. \\ \left. - \sum\limits_{j=1}^{J}\sum\limits_{k=1}^{K}(x_{jk}\tilde{\tilde{v}}_{jk} + \eta(x_{jk})w_{jk}) - b\vartheta \sum\limits_{k=1}^{K} x_k \geq \overline{F}_1 \right\}(\alpha_1^{(1)}) \geq \beta_1^{(1)} \\ Ch\left\{\sum\limits_{k=1}^{K}(1-\theta_{jk})y_{jk}/\tilde{\tilde{D}}_j \geq \overline{F}_{2j}\right\}(\alpha_{2j}^{(1)}) \geq \beta_{2j}^{(1)}, \quad j = 1, 2, \cdots, J \\ \sum\limits_{k=1}^{K}(1-\theta_{jk})x_{jk} \leq C \\ (1-\vartheta)\sum\limits_{j=1}^{J}\sum\limits_{k=1}^{K}(1-\theta_{jk})x_{jk} = \sum\limits_{k=1}^{K}(1-\zeta_k)x_k \\ \sum\limits_{k=1}^{K} x_k = y \\ Ch\left\{\sum\limits_{k=1}^{K}\eta(y_{jk})\tilde{\tilde{h}}_{jk} \leq T_j\right\}(\gamma_j^{(2)}) \geq (\delta_j^{(2)}), \quad j = 1, 2, \cdots, J \\ x_k \leq t_k, \sum\limits_{j=1}^{J} x_{jk} \leq t_k, \quad k = 1, 2, \cdots, K \\ x \geq 0, x_k \geq 0, x_{jk} \geq 0, \quad j = 1, 2, \cdots, J, \ k = 1, 2, \cdots, K. \end{cases} \end{cases} \tag{6.5}$$

6.3.1.2 Lower Level Model

The production base makes its decision of the output, after receiving the price given by the distribution center. The only objective of the production is to maximize its profit:

$$f = (x - p')y, \tag{6.6}$$

the level model for the distribution center can formulated as:

$$\begin{cases} \max\limits_{y} f = \left(x - \frac{p_0'}{\sqrt{y}}\right) y \\ \text{s.t.} \begin{cases} y \le Y \\ y \ge 0. \end{cases} \end{cases} \tag{6.7}$$

6.3.1.3 Overall Model

As mentioned above, the problem considered in this paper is formulated as a bilevel multiobjective programming model. As the production center makes decision first, the production center is the leader, while the contractor is the follower. By embedding lower level model (6.7) in upper level model (6.5), we develop the global model as:

$$\begin{cases} \max\limits_{x, x_k, x_{jk}} \left[\overline{F}_1, \overline{F}_{21}, \overline{F}_{22}, \cdots, \overline{F}_{2J}\right] \\ \text{s.t.} \begin{cases} Ch\left\{\sum\limits_{j=1}^{J} \frac{p_j^0}{\tilde{\overline{D}}_j} \sum\limits_{k=1}^{K}(1-\theta_{jk})x_{jk} - xy - \sum\limits_{k=1}^{K}(x_k v_k + \eta(x_k)w_k) \right. \\ \left. -\sum\limits_{j=1}^{J}\sum\limits_{k=1}^{K}(x_{jk}v_{jk} + \eta(x_{jk})w_{jk}) - b\vartheta\sum\limits_{k=1}^{K} x_k \ge \overline{F}_1\right\}(\alpha_1^{(1)}) \ge \beta_1^{(1)} \\ Ch\left\{\sum\limits_{k=1}^{K}(1-\theta_{jk})y_{jk}/\tilde{\overline{D}}_j \ge \overline{F}_{2j}\right\}(\alpha_{2j}^{(1)}) \ge \beta_{2j}^{(1)}, \quad j = 1, 2, \cdots, J \\ \sum\limits_{k=1}^{K}(1-\theta_{jk})x_{jk} \le C \\ (1-\vartheta)\sum\limits_{j=1}^{J}\sum\limits_{k=1}^{K}(1-\theta_{jk})x_{jk} = \sum\limits_{k=1}^{K}(1-\zeta_k)x_k \\ \sum\limits_{k=1}^{K} x_k = y \\ Ch\left\{\sum\limits_{k=1}^{K}\eta(y_{jk})\tilde{\overline{h}}_{jk} \le T_j\right\}(\gamma_j^{(2)}) \ge (\delta_j^{(2)}), \quad j = 1, 2, \cdots, J \\ x_k \le t_k, \sum\limits_{j=1}^{J} x_{jk} \le t_k, \quad k = 1, 2, \cdots, K \\ x \ge 0, x_k \ge 0, x_{jk} \ge 0, \quad j = 1, 2, \cdots, J,\ k = 1, 2, \cdots, K, \end{cases} \\ \text{where } y \text{ solves} \\ \quad \begin{cases} \max\limits_{y} f = \left(x - \frac{p_0'}{\sqrt{y}}\right) y \\ \text{s.t.} \begin{cases} y \le Y \\ y \ge 0. \end{cases} \end{cases} \end{cases} \tag{6.8}$$

6.4 Solution Procedure

The main solution procedure for bilevel model (6.8) model consists of two steps: transforming the bilevel model into a single level model and designing a hybrid genetic algorithm.

6.4.1 KKT Transformation

Although simplest bilevel linear programming is a NP-hard problem [3], the lower level model of (6.8) is so simple that can be transformed by KKT condition. In order to use the KKT condition, we rewrite the lower level model as the following standard form:

$$\begin{cases} \min\limits_{y} -f = \sqrt{y}p_0' - xy \\ \text{s.t.} \begin{cases} g_1(y) = y - Y \leq 0 \\ g_2(y) = -y \leq 0, \end{cases} \end{cases} \tag{6.9}$$

$$\begin{cases} \frac{p_0'}{2\sqrt{y}} - x + \lambda_1 - \lambda_2 = 0 \\ \lambda_1(y - Y) = 0 \\ -\lambda_2 y = 0 \\ \lambda_1, \lambda_2 \geq 0. \end{cases} \tag{6.10}$$

In a real production-distribution system, the output y must be positive. It follows from $-\lambda_2 y = 0$ that $\lambda_2 = 0$. If $\lambda_1 = 0$, $y = \frac{p_0'^2}{4x^2}$, and $\lambda_1 > 0$, $y = Y$. Here we discuss the two cases respectively.

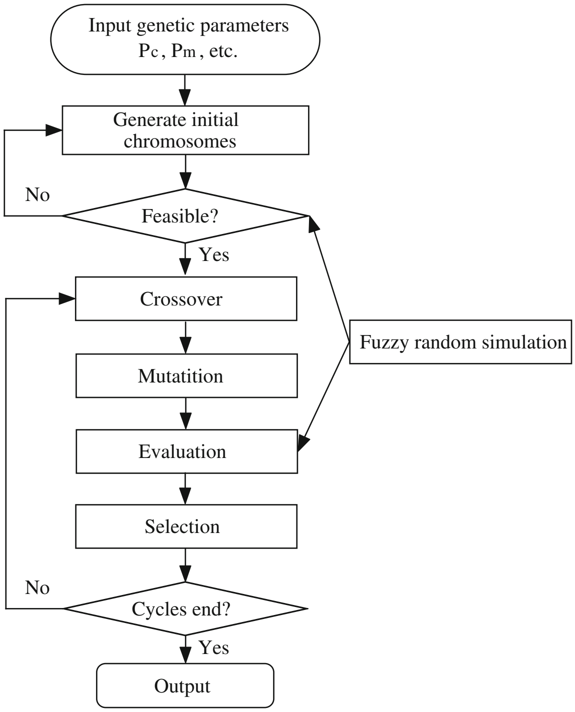
Case 6.1 $\lambda_1 = 0$, $y = \frac{p_0'^2}{4x^2}$. For this case,

$$f = \left(x - \frac{p_0'}{\sqrt{y}}\right) y = -\frac{p_0'^2}{4x} < 0$$

implies a contradiction with reality, i.e., no one will do a business at a loss.

Case 6.2 $\lambda_1 > 0$, $y = Y$. For this case, $x = \frac{p_0'}{2\sqrt{Y}} + \lambda_1$. It follows from $\lambda_1 = x - \frac{p_0'}{2\sqrt{Y}} > 0$ that the lower level model can be transformed into the inequality constraint $x > \frac{p_0'}{2\sqrt{Y}}$.

Fig. 6.2 The flowchart of the fuzzy random simulation-based genetic algorithm



6.4.2 *Fuzzy Random Simulation-based Genetic Algorithm*

After transforming (6.8) into a single-level model, we design the so-called fuzzy random simulation-based genetic algorithm to solve it. Simulation is an imprecise technique which provides only statistical estimates rather than exact results and is also a slow and costly way to study problems. However, it is indeed a powerful tool dealing with complex problems without analytic techniques. Fuzzy random simulation is a twofold simulation of fuzzy simulation and stochastic simulation. The fuzzy random simulation-based genetic algorithm is to embed the fuzzy random simulation technique into genetic algorithm.

The overall procedure of the fuzzy random simulation-based genetic algorithm is illustrated by Fig. 6.2.

6.5 Practical Application

The problem between a organic agricultural products base in Mianyang and a distribution center in Chengdu, is used as a practical application example.

Table 6.1 Fixed transportation costs, $w_k, k = 1, 2, 3$ (yuan)

	Base-distribution center					
Fleet 1	2,000					
Fleet 2	3,600					
Fleet 3	5,000					
	Distribution center-customers					
	Guangzhou	Wuhan	Changsha	Nanjing	Hangzhou	Nanchang
Fleet 1	300	320	340	360	380	400
Fleet 2	400	420	440	460	480	500
Fleet 3	500	520	540	560	580	600

Table 6.2 Unit transportation costs, $v_k, k = 1, 2, 3$ (yuan/ton)

	Base-distribution center					
Fleet 1	1.2					
Fleet 2	1.0					
Fleet 3	0.8					
	Distribution center-customers					
	Guangzhou	Wuhan	Changsha	Nanjing	Hangzhou	Nanchang
Fleet 1	1.1	1.2	1.3	1.4	1.5	1.6
Fleet 2	0.9	1.0	1.1	1.2	1.3	1.4
Fleet 3	0.7	0.8	0.9	1.0	1.1	1.2

6.5.1 Presentation of Case Problem

The base in Mianyang produces a kind of organic agricultural product-mini jujube, which is very popular with the market. The distribution center has the functions of processing, inventory and distribution. There are 6 customers in all from Guangzhou, Wuhan, Changsha, Nanjing, Hangzhou and Nanchang. The production capacity of this base is 100,000 tons and budget is 200,000,000 yuan. The aspired delivery time of the 6 customers are 36, 54, 48, 36, 60 and 54 h, respectively. There are 3 transport fleet belong to the distribution center with capacities of 20,000, 30,000 and 50,000 tons, respectively. For the base, the unit production cost can be presented by the following fuzzy random variable: $\tilde{\bar{e}} = (\bar{e}, 500, 100)_{LR}, \bar{e} \sim \mathcal{N}(60{,}000, 100)$.

Since the road conditions, distances and status of the products are different between base-distribution center and distribution center-customers, the fixed transportation cost and the unit transportation cost differs for the same fleet. The fixed transportation costs and the unit transportation costs of the three fleets are listed in Tables 6.1 and 6.2, respectively.

A larger fleet has higher fixed cost but lower unit cost due to the economies of scale. On the contrary, a smaller fleet has lower fixed cost but higher unit cost.

The loss rates during transportation are listed in Table 6.3.

Table 6.3 Loss rates during transportation (%)

	Base-transit center					
Fleet 1	2					
Fleet 2	1.5					
Fleet 3	1.2					
	Transit-customers					
	Guangzhou	Wuhan	Changsha	Nanjing	Hangzhou	Nanchang
Fleet 1	0.6	0.7	0.8	0.9	1.0	1.1
Fleet 2	0.5	0.6	0.7	0.8	0.9	1.0
Fleet 3	0.4	0.5	0.6	0.7	0.8	0.9

Table 6.4 Customers' demands (ton)

Guangzhou	$\tilde{\overline{D}}_1 = (\overline{D}_1, 100, 200)_{LR}, \overline{D}_1 \sim \mathcal{N}(13{,}000, 10)$
Wuhan	$\tilde{\overline{D}}_2 = (\overline{D}_2, 100, 200)_{LR}, \overline{D}_2 \sim \mathcal{N}(14{,}000, 10)$
Changsha	$\tilde{\overline{D}}_3 = (\overline{D}_3, 100, 200)_{LR}, \overline{D}_3 \sim \mathcal{N}(15{,}000, 10)$
Nanjing	$\tilde{\overline{D}}_4 = (\overline{D}_4, 100, 200)_{LR}, \overline{D}_4 \sim \mathcal{N}(16{,}000, 10)$
Hangzhou	$\tilde{\overline{D}}_5 = (\overline{D}_5, 100, 200)_{LR}, \overline{D}_5 \sim \mathcal{N}(17{,}000, 10)$
Nanchang	$\tilde{\overline{D}}_6 = (\overline{D}_6, 100, 200)_{LR}, \overline{D}_6 \sim \mathcal{N}(18{,}000, 10)$

Table 6.5 Unit prices, (yuan/ton)

Guangzhou	$\tilde{\bar{p}}_1 = (\bar{p}_1, 1, 2)_{LR}, \bar{p}_1 \sim \mathcal{N}(20, 2)$
Wuhan	$\tilde{\bar{p}}_2 = (\bar{p}_2, 1, 2)_{LR}, \bar{p}_2 \sim \mathcal{N}(22, 2)$
Changsha	$\tilde{\bar{p}}_3 = (\bar{p}_3, 1, 2)_{LR}, \bar{p}_3 \sim \mathcal{N}(24, 2)$
Nanjing	$\tilde{\bar{p}}_4 = (\bar{p}_4, 1, 2)_{LR}, \bar{p}_4 \sim \mathcal{N}(26, 2)$
Hangzhou	$\tilde{\bar{p}}_5 = (\bar{p}_5, 1, 2)_{LR}, \bar{p}_5 \sim \mathcal{N}(28, 2)$
Nanchang	$\tilde{\bar{p}}_5 = (\bar{p}_6, 1, 2)_{LR}, \bar{p}_6 \sim \mathcal{N}(30, 2)$

The inventory capacity of the distribution center is 96,000 tons and unit storage cost is 10 yuan/ton. The customers' demands are listed in Table 6.4. The unit prices to different customers are listed in Table 6.5.

6.5.2 *Results and Discussion*

To show the practicality and efficiency of the optimization method for the benefit trade-off problem presented in this paper, the rough simulation and interactive fuzzy programming combined with hGA is conducted and ran on MATLAB. First, the rough simulation is conducted 30 times of running the rough simulation is finished, and the mean value of the outcomes is.

Table 6.6 Optimal transport scheme as $\alpha = 0.6$

	Base-distribution center					
Fleet 1	20,000					
Fleet 2	30,000					
Fleet 3	50,000					
	Transit center-customers					
	Guangzhou	Wuhan	Changsha	Nanjing	Hangzhou	Nanchang
Fleet 1	4,000	3,650	–	2,800	6,260	1,800
Fleet 2	2,600	17,000	3,970	–	8700	7,400
Fleet 3	8,800	8,750	12,730	11,400	–	6,090

Table 6.7 Optimal transport scheme as $\alpha = 0.7$

	Base-distribution center					
Fleet 1	18,000					
Fleet 2	29,000					
Fleet 3	47,700					
	Transit center-customers					
	Guangzhou	Wuhan	Changsha	Nanjing	Hangzhou	Nanchang
Fleet 1	3,800	3,750	–	2,660	6,300	1,800
Fleet 2	2,700	16,000	3,590	–	8,800	7,200
Fleet 3	8,600	8,800	13,030	11,600	–	6,100

Table 6.8 Optimal transport scheme as $\alpha = 0.8$

	Base-distribution center					
Fleet 1	18,000					
Fleet 2	29,000					
Fleet 3	47,000					
	Transit center-customers					
	Guangzhou	Wuhan	Changsha	Nanjing	Hangzhou	Nanchang
Fleet 1	3,800	3,750	–	2,660	6,300	1,800
Fleet 2	2,700	16,000	3,590	–	8,800	7,200
Fleet 3	8,600	8,200	13,030	11,300	–	5,700

As shown from these tables, the optimal values of the objective function get worse with the confidence levels increasing since the feasible religion narrows. Higher confidence levels means lower risk degree but lower return. How to set confidence levels depends on decision maker's attitude towards risk (Tables 6.6, 6.7 and 6.8).

6.6 Conclusions

In this paper, we developed a novel multiobjective programming model with rough interval parameters, and proposed a rough interval goal programming approach and spanning tree-based genetic algorithm to tackle the model. The model and algorithm are applied to a practical problem. The experimental results and the comparison analysis illustrate the effectiveness of our model and algorithm.

Several extensions of the proposed approach are worthwhile further investigating. Further study on rough intervals, such as other operators and order relations, can be discussed as basis of rough interval programming. More rough interval programming models should be investigated. Also, improving algorithm quality and more practical applications are important issues for future research.

Acknowledgments This research was supported by the Programs of NSFC (Grant No. 70831005, 71273036, 71302134), Projects of International Cooperation and Exchanges NSFC (Grant No. 71011140076), the Research Foundation of Ministry of Education for the Doctoral Program of Higher Education of China (Grant No. 20130181110063), "985" Program of Sichuan University (Innovative Research Base for Economic Development and Management), Sichuan University Young Teachers Scientific Research Start Funds (Grant No. 2012SCU11016) and the Key Program of Sichuan System Science and Enterprise Development Research Center (Grant No.Xq13B04).

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Chapter 7
A Multi-attribute Reverse Auction Decision Making Model Based on Multi-objective Programming

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Abstract Multi-attribute reverse auction has been widely used for the centralized procurements of large enter-prise groups. The Enter-prises procure goods according to their price and quality attributes, then bid attributes are usually classified into technical attributes and business attributes, which are evaluated by technical experts and business managers whose objectives are different. Technicians are aimed at making good performance and quality optimal, while managers want to minimize the cost. This paper focuses on the development process of reverse auction and tells the features of multi-attribute reverse auction. Then a multi-objective programming model has been established considering the buyer's utility and cost to be the objectives according to the preferences of technicians and managers. Besides, Genetic Algorithms (GA) is applied to solve the calculation to demonstrate utility and availability of the model. Finally, an example is taken to make readers easier to understand.

Keywords Multi-attribute auction · Reverse auction · Multi-objective programming · Genetic algorithm

7.1 Introduction

Since Myerson [15] found out the optimal auction mechanism based on SIPV (symmetry, independent, and personal value) information structure to make the seller's auction proceeds maximal for the first time, auction theory has made a great development. Milgrom and Weber [14] pointed out some theories of auctions and used Nash Equilibrium in the analysis of competitive bidding. Then bidders can offer for the combination of any subject matter which is named combinatorial auction.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_7,

In a combinatorial auction, a seller is faced with a set of price offers for various bundles of goods, and his aim is to allocate the goods in a way that maximizes his revenue. This optimization problem is intractable in the general case, even when each good has only a single unit [18]. Some overviews of applying related tree search algorithms to combinatorial auctions have been written [6, 16]. With the realm of supply management, the reverse auction has become an increasingly widespread topic in the trade. It is also named procurement auction which is a development of traditional auction. Reverse auctions are simply traditional auctions in reverse [19]. In the traditional auction, a seller offers service or a good for sale to the highest bidder. While in a reverse auction, a buyer invites a tender for the supply of a specific quantity of goods or service. As the application of reverse auctions, it has become increasingly common in the B2B domain, but more and more new problems come into being in practice. Except for the price, buyers usually watch other attributes when they procure something. Che [3] performed a pioneering study that he put forward a kind of two-dimensional multi-attribute auction, which is composed of price and quality. Then multi-attribute reverse auction appears.

In process of the auction evolution, so many theories and mechanisms are developed. Kelly and Steinberg [12] applied Multiple Winners combinatorial Auction. Che [3] used a utility function to score bids to support governmental procurement processes. Bichler [2] defined multi-attribute auction as a kind of auction patterns in which more attributes other than price should be considered. Dekrajangpetch and Shebl [8] used linear programming method to solve the problem of multi-attribute auction for the first time. Chen and Wang [4] used Genetic Algorithm for solving winner determination in Combinatorial Auctions. Cheng [5] used a bi-level programming to solve the problem of reverse auction with buyer Csupplier negotiation. Yuan [20] made a liner programming model to realize decision making in which the weight is evaluated in AHP.

Multi-attribute reverse auction is one way of the electronic procurement in supply chain, in which the suppliers and buyers often consider many different attributes like delivery, date, quality and so on when they trade, these attributes are classified into technical attributes and business attributes respectively evaluated by technical experts and business managers whose objectives are different. Technicians are aimed at making good performance and quality optimal, and managers want to minimize the cost, which makes it possible to build a multi-objective programming. Actually, under some circumstance, expected utility of the buyer increases with the increase in the number of suppliers according to Ray et al. [17]. So many companies have moved to a multiple attributes policy, in which large amounts of less critical goods such as office furniture are procured from multiple rather than single supplier. To find the optimum combination of suppliers' offers which satisfies the buyer's demand and maximizes a predetermined scoring function.

During the last two decades, there are so many methods to solve the multi-objective programming, such as graphical method, evaluating function method, interactive programming method and geometry model method and so on. But when the functions are very complex, these methods will not solve multi-objective programming effectively. However, recently a number of multi-objective evolutionary algorithms (MOEA) have been suggested. Genetic Algorithms (GA) are adaptive methods which maybe used to solve optimization problems [1]. Since the first practical implementation of using genetic-base search to deal with the problem vector evaluated genetic algorithm (VEGA) was raised by DavidSchaffer in 1984. Then an idea of using Pareto-based fitness assignment was proposed [10]. Then comes with weighted sum with elitist preserve [13]. These years, GA has developed so much. Since the 1980s, several fitness assignment mechanisms have been proposed and applied in multi-objective optimization problems [9].

In the basic of above, multi-attribute reverse auction is so important, but only a little papers use multi-objective programming. Though there exists GA method applied in auction problems, GA method used in the multi-attribute problems with multi-objective programming is less. Based on the demand of current practice of reverse auction, this paper focuses on both aims of technicians and managers to establish a multi-attribute model that we set the buyer's maximal utility and minimal cost to be the objectives to disclose inherent mechanism. The paper is organized as follows: Sect. 7.2 states the problem and presents the basic model assumptions, and then formulates a theoretical model to search for the winners of the auction. Besides, the process and procedure of genetic algorithms are described in that section. Section 7.3 presents a numerical simulation computation for the optimal model with the method of GA. Section 7.4 draws main conclusions, managerial implications, limitations, and directions for future work.

7.2 Modeling

This section describes some assumptions and common notations to make the model set up. And model formulation process is followed. Following the last is the solution for the modeling based on GA.

7.2.1 Problem Statement

Taking the buyers' personal preferences and specific demands into consideration, they may choose more than one winners from all suppliers. So a multi-objective mixed programming model is set for the multi-winners' decision-making. General framework for the model can be described as follows: buyers offer goods attributes they need, and they point out the weight of each attribute; then the buyers make up a scoring function for each attribute which only themselves know them and suppliers don't know, and they view the total scores as their total utility; finally, the ones who can make the buyers' total utility maximum and total cost minimum will win the bid.

In order to simplify the research work, some assumptions are put forward as follows:

- There are n suppliers and one buyer, the buyer procure a kind of good with $1 + m$ attributes which contain a price attribute and m quality attributes; besides, the buyer will choose more than one suppliers.

- The objects have independent private values, it is that only suppliers themselves know their attributes' values, and the objects have no effect on other suppliers.
- Each attribute of the objects can be quantified.
- There is no expenditure on delivery or transportation service for buyers.
- The transaction cost is zero.

The common notations of the problem are shown below:

n total number of invited suppliers,
m total number of quality attributes,
p_i unit bid price of supplier i,
q_{ij} measurement of the jth attribute offered by supplier i, where $i = 1, 2, \cdots, n$; $j = 1, 2, \cdots, m$,
q_i vector of supplier i's attribute, where $q_i = (q_{i1}, q_{i2}, \cdots, q_{im})$,
$V_i(q_{ij})$ utility of the jth attribute offered by supplier i to the buyer,
$V_i(p_i)$ utility of the i supplier' price,
w_j weight of quality attribute j,
w_p weight of price attribute,
$Q_{\min}$ minimum order quantity for the buyer,
$Q_{\max}$ maximum order quantity for the buyer,
Q_i supplier i's quantity supplied,
$R_{\min}$ minimum winners of the bid,
$R_{\max}$ maximum winners of the bid,
$d_{i\max}$ supplier i's maximum quantity supplied,
L maximum fund accepted by the buyer,
x_i binary variable, equal to 1 if supplier i is one winner; 0 otherwise,
V buyer's total utility of all winners' goods,
C buyer's total cost of all winners' goods.

7.2.2 Model Formulation

In the process of bidding, a supplier is not aware of other suppliers' bidding condition, including price, each attribute's measurement and quantity of his goods. Similarly, the supplier does not know the buyer's scoring function. That is all the suppliers and buyers are equal and honest.

Before the bidding, the buyer will give each attribute a weight, and the weight must satisfy: $w_p + \sum_{j=1}^{m} w_j = 1$. Suppliers can think over their bidding price according to each weight.

The buyer's utility is sum of supplier's value of price and quality attributes, it is represented by sum of all the attributes' measurement. So the unit good's utility can be indicated by formula: $\overline{V}_i = \sum_{j=1}^{m} w_j V_i(q_{ij}) + w_p V_i(p_i)$.

If supplier is chosen to be a winner and he will provide goods to the purchaser, the utility bringing to the purchaser is defined as: $V_i = [\sum_{j=1}^{m} w_j V_i(q_{ij}) + w_p V_i(p_i)] Q_i x_i$.

As a result, the objective function of the auction problem is to maximize purchaser's utility:

$$\max V = \sum_{i=1}^{n} V_i. \tag{7.1}$$

Obviously, the other goal is to make purchaser's cost, namely:

$$\min C = \sum_{i=1}^{n} Q_i p_i x_i. \tag{7.2}$$

Constraints on this multi-attribute reverse auction:
Firstly, the model is a decision making model, because there are so many bidders in the multi-attribute reverse auction, the most important thing is to make sure the winners, that is:

$$x_i \in \{0, 1\}. \tag{7.3}$$

If one supplier i is chosen to provide goods, the quantity of his available goods has a maximal limitation and cannot be negative: $0 \le Q_i \le d_{i\max} x_i$. The buyer considers the situation of all aspects, he decides to choose more than one suppliers, so he determines the number of winners as follows: $R_{\min} \le \sum_{i=1}^{n} x_i \le R_{\max}$. To satisfy the buyer's need, the winners' total goods they provide must in the range of: $D_{\min} \le \sum_{i=1}^{n} x_i Q_i \le D_{\max}$. All companies won't cost too much to procure, no exception for the buyer in the multi-attribute reverse auction, so the total cost of the buyer has a limitation for:

$$\sum_{i=1}^{n} p_i x_i Q_i \le L. \tag{7.4}$$

7.2.3 The General Model

Taking all above factors into consideration results in a model group to provide an analytical framework for the explanation of purchaser's benefit from auction explicitly. The relationship can be described as a multi-objective mixed integer non-liner programming (MOMINLP). The objective functions for the decision maker as shown in Eqs. (7.1) and (7.2) reflect the multiple goals of the procurer in the auction. The equations and inequalities in Eq. (7.3). Equation (7.4) describes the decision making process. Therefore, by integrating the equations, objective functions and constraints, a multi-objective programming can be formulated as:

$$\begin{cases} \max V \\ \min C \\ \text{s.t.} \begin{cases} x_i \in \{0, 1\} \\ 0 \leq Q_i \leq d_{i\max} x_i \\ R_{\min} \leq \sum_{i=1}^{n} x_i \leq R_{\max} \\ D_{\min} \leq \sum_{i=1}^{n} x_i Q_i \leq D_{\max} \\ \sum_{i=1}^{n} p_i x_i Q_i \leq L. \end{cases} \end{cases} \tag{7.5}$$

From the model (7.5) we all know that it is a multi-objective mixed integer nonliner programming model, the solution of the model is very complex, so some variable approaches are simplified. In the model group, the supplier i's utility function of each attribute $V_i(q_{ij})$ is given by the buyer, and we set all suppliers' utility function for each attribute the same in order to simplify the calculation. Besides, each function is liner and constant for its variable, but the variables in utility functions are treated as parameters in model group. Sometimes Q_i is constant but it also can be an integer thus be a discrete variable, so Q_i is processed into a constant variable for simple calculation. Although the model (7.5) specifies the optimization formulation to determine the optimal amount of winners for the goods, they cannot be integrated to generate to determine who is the winner, because x_i is the determining factor.

7.2.4 Solution to the Modeling Based on GA

The proposed model (7.5) provides an optimization configuration method for winner's determination problem to realize the utility maximum and cost minimum. However, the variables of x_i and Q_i are mixed integer variables, and the objective functions and some constraints are nonlinear, so the model is a NP hard problem. GA do not need many mathematical requirements and can handle all types of objective functions and constraints. Hence, a procedure based on GA is designed to look for optimal strategies for the auction and further help the procurer to make better decisions. To deal with the multiple objectives a weighted-sum procedure is adopted in process of treating the problem. Only when the solution set is convex that the objective in the form of a weighted-sum makes it possible to find the optimal Pareto solutions. To ensure the effectiveness of the solution, the unifying the order of magnitude must be performed before the weighted-sum procedure. In view of the feasibility of the solution, we make the objective functions dimensionless. The process of GA is:

- Initialization: setting the maximum generation T, population size M, crossover probability P_c, mutation probability P_m, randomly generate M individuals as the initial population P_0.

- Chromosome coding: the basic genetic algorithm using a fixed length of binary string to represent an individual group of populations, the allele is made up of binary notation set {0, 1}.
- Individual evaluation: calculating the fitness of the individuals in the population P_t.
- Selection: acting the selection operator on the population. According to the chromosome fitness and problems of the requirements, select the chromosome in the population P_t, the higher the fitness of the chromosome, the bigger probability to save to P_{t+1}, and the smaller the opposite, or even to be eliminated.

Here we use Pareto Genetic Algorithm with Preserving Pareto to solve our problem.

7.3 Numerical Analysis and Results

To verify the validity of the algorithm and feasibility of the settling method, a practical problem for example is given in this section. Sometimes, government procures some machines or some furniture by multi-reverse auction. For example, government wants to procure some air conditions. The lowest limit of total amount is 1,000 units, while the highest limit is 1,200 units. The specific requirements for air conditions are shown in Table 7.1. Here, the weight of each attribute has been determined in advance, and each attribute can be assessed by a linear utility functions.

According to the government's requirements, there are five suppliers come from 50 bidders can almost satisfy the demand. The detail every bidding is shown in Table 7.2. According to the principle of our multi-attribute model, we could establish a specific multi-attribute reverse auction model as shown in model (7.6). The candidate with larger V and smaller C will be taken into consideration first.

$$\begin{cases} \max V = \sum_{i=1}^{5} V_i \\ \min C = \sum_{i=1}^{5} Q_i p_i x_i \\ \text{s.t.} \begin{cases} x_i \in \{0, 1\} \\ 0 \le Q_1 \le 500 x_i \\ 0 \le Q_2 \le 450 x_i \\ 0 \le Q_3 \le 300 x_i \\ 0 \le Q_4 \le 400 x_i \\ 0 \le Q_5 \le 300 x_i \\ 2 \le \sum_{i=1}^{5} x_i \le 3 \\ 1{,}000 \le \sum_{i=1}^{5} x_i Q_i \le 1{,}200 \\ \sum_{i=1}^{5} p_i x_i Q_i \le 1{,}000. \end{cases} \end{cases} \tag{7.6}$$

Table 7.1 Government's requirements

Attributes	Requirements	Weights	Utility functions	Function values
Color	White; red; black	0.05	White: $S_{11} = 100$; red: $S_{12} = 80$; black: $S_{13} = 60$	$S_{11} = 100$; $S_{12} = 80$; $S_{13} = 60$
Frequency conversion (yes or no)	Yes	0.2	$S_2 = 100$	100
Energy efficiency ratio	3.0; 3.2; 3.4	0.1	$S_3 = 100x - 240$	60; 80; 100
Air current indoor (m^3/min)	5–15	0.15	$S_4 = 120 - 4x$	Depending on x
Price (RMB 10K)	$0.6 \leq P \leq 1$	0.5	$S_5 = 220 - 200p$	Depending on p

Table 7.2 The details of each bidding

No.	S_1	S_2	S_3	S_4	S_5	Quantity
1	White	Yes	3.0	9	0.80	500
2	Black	Yes	3.4	11	0.88	450
3	Red	Yes	3.2	10	0.85	300
4	Black	Yes	3.4	12.5	0.86	400
5	White	Yes	3.2	9	0.90	300

We use GA to solve the problem: First, we set the $Gen = 200$, $Pop = 500$, $P_m = 0.8$; $P_c = 0.5$; then make evaluation that calculate the maximum and the minimum of the two functions respectively and use weighted-sum to calculate the total fitness, third use roulette wheel selection method, assign chromosomes which are selected to the new matrix; and next crossover and mutation.

We use MATLAB to realize the process, and through calculation, we can obtain the orders of the given 5 bidders according to the result: the government firstly assign 450 units to bidder 1, then 409 units to bidder 2 and 257 units to bidder 5, while the total amount is'just equal to 1,116 units, which satisfies the upper bound of buyer's quantity demanded. Therefore, bidder 1, 2, 5 are winners, while bidder 3 and bidder 4 have to be eliminated.

7.4 Conclusions

This paper uses GA to solve the problem of multi-attribute reverse auction. In order to satisfy buyer's requirements, the decision-making problems at the buyer side is formulated as a multi-objective programming although the objective functions are complex so much. This method can help some companies to make up their minds when they need to conduct multi-attribute reverse auctions.

However, there exists some constraints in our paper. The model is based on a strict and ideal assumptions that auctions of more kinds of goods cannot be used here. Moreover, the weight of each attribute is hard to determine for the buyers and they don't have any standards. Then buyer makes a range of quantity that it may result in inefficient search of the solution. Besides, the authors have no many methods to deal with the mixed-integer variables in GA for our limitation knowledge of GA.

We will apply learning techniques to update these problems in our future work and we will extend our work to a more realistic and sophisticated occasions. Thus, we believe our research will be more meaningful.

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Chapter 8
The Efficiency Evaluation of Chinese Film and Television Industry Listed Companies Based on DEA Method

Guangmin Li, Qiong Lei and Yongzhong Yang

Abstract This paper uses the CCR and BCC model of DEA method to empirically analyzes the efficiency of 16 listed companies in film and television industry from 2010 to 2012. Splitting the film and television industrial chain into three parts: technical support and information transmission, production and distribution, channels and network operations, and analyze the technical efficiency and scale benefits of each part. The result shows the whole industry is growing slowly, comprehensive technical efficiency is small decline, pure technical efficiency keep on growing stably, scale efficiency shows a obviously trend of decreasing. The scale efficiency of technical support and information transmission is obvious declined, the technical efficiency of production and distribution is outstanding, and the pure technical efficiency of channels and network operations continue to rise steadily. This paper also gives the policy suggestion that the film and television industry need to pay more attention to the SE improvement.

Keywords DEA · Film and television industry · Efficiency evaluation · Empirical analysis

8.1 Introduction

Facing the impact of digital technology and information technology, film and television industry is in the process of institutional innovation and technical transformation, such as deepening marketization, sowing separation, corporate restructuring. It is needed to evaluate the listed companies' adaptation under the new background of new technology and policy. With China's economic development and people's income growth, film and television industry as China's "first media" is the main way

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_8,

to improve the quality of people's spiritual and cultural life, now it's an integral part of people's daily, so how to improve the efficiency of the broadcasting industry has become a very urgent practical need. Researching on the representative and efficient listed company is providing demonstration and guidance for the sustainable development of film and television enterprises in the future.

In the past, scholars have studied the performance of film and television from different perspectives. Yue used the "structure-behavior-performance" analysis method to explore the impact of administrative monopoly on the economic performance in Chinese film and television industry [8]. From the public service perspective, Fang builds a seven-dimensional public service performance evaluation system to measure the ability of its public services [4]. Chen and Li point out that the performance evaluation of film and television industry is tend to meticulous management [3]. Min and Li [6] has carried on the empirical research on the return to scale about 11 listed companies in Chinese media industry. Li and Li [5] carried on the empirical research of listed cultural media companies about their technology innovation efficiency. But there is no study to work on the efficiency evaluation of Chinese film and television industry listed companies by analyzing time series data based on industrial chain. This paper uses the CCR and BCC model of DEA method to empirically analyzes the efficiency of 16 listed companies in film and television industry from 2010 to 2012 based on industrial chain. And also gives the policy suggestion that the news and publishing industry need to pay more attention to the SE improvement.

8.2 The Introduction of DEA Method and Its Model

Data Envelopment Analysis was created by Charnels, Cooper et al. in 1978 [1, 2]. It's a nonparametric statistical method to evaluate the effectiveness of multi-input and multi-output among the similar Decision making units by mathematical programming model. Each DMU is an economic system or a production process, which has similar goals and the external environment, the same input and output index. The CCR model is the first model based on constant returns to scale (CRS), then developed the BCC model under the assumption of variable returns to scale (VRS). While the new DEA models continue to produce, they all are established on the basis of the CCR and BCC model. In recent years, BCC and CCR model were widely used to assess the efficiency of listed companies by domestic scholars, containing the real estate industry, agriculture industry, the power industry, the pharmaceutical industry, retail industry. Therefore, this paper also uses the CCR and BCC model.

Defining input index as $X = (x_1, x_2, \cdots, x_i, \cdots, x_n, x_i)$ represents the ith input; output index as $Y = (y_1, y_2, \cdots, y_i, \cdots, y_m, y_i)$ represents the ith output; (X_j, Y_j) stands for input–output vector of the jth decision making unit; (X_0, Y_0) represents the actual corresponding index of DMU. Build linear programming equation of effective CCR model [7].

$$
\begin{cases}
\min \theta \\
\text{s.t.} \begin{cases}
\sum_{i=1}^{n} \lambda_i x_i + s^- = \theta X_0 \\
\sum_{i=1}^{n} \lambda_i y_i - s^+ = \theta Y_0 \\
\lambda_i \geq 0, i = 1, 2, \cdots, n \\
s^+ \geq 0, s^- \geq 0.
\end{cases}
\end{cases}
\tag{8.1}
$$

S^- and S^+ both are slack variables, representing input redundancy and output deficiency, θ is the effective value of DMU. Adding a convexity assumption constraint in the linear programming, we can get the BBC model. In the CCR and BCC models, θ is expressed as integrated technical efficiency (TE), pure technical efficiency (PTE) and scale efficiency (SE), and $TE = PTE \times SE$. When $\theta = 1$, $S^- = 0$ and $S^+ = 0$, namely the state of input and output achieve the best combination, which is called DEA effective. When $\theta = 1$, $S^- \neq 0$ or $S^+ \neq 0$, called weakly effective DEA. Namely reduce inputs S^-, output Y_0 is unchanged. When $\theta < 1$, the DEA is invalid, we can reassemble on the input and output and keep the output Y_0 remains unchanged.

Thus DEA method has the following four advantages. First, based on objective data, the evaluation result is more objective. Second, don't need to consider about the multiple dimensions and weights between input and output indicators. Third, needn't to construct a basic production function or estimate function parameters. Finally, economic significance is clearer. The evaluation of the effectiveness of each DMU is specific as TE, PTE, SE, which is a comprehensive assessment, providing more management information.

8.3 Empirical Analysis

8.3.1 Selecting the Samples

Based on the industry classification of China Securities Regulatory Commission (CRCS), this paper select the second category of film and television industry, information transmission, the first category of computer application services industry, containing 16 listed companies in film and television industry. Then split the film and television industrial chain into three parts, technical support and information transmission, production and distribution channels and network operations. Confirm the position in the film and television industrial chain combined with each listed company's business scope, which includes 6 technical support and information transmission companies, 5 program production and distribution companies and 5 channels and network operation companies. The sample data in this article are all from the 2010 to 2012 annual reports of listed companies.

Table 8.1 The PTE, TE and VRS of listed companies in Chinese film and television industry from 2010 to 2012

	2010			2011			2012		
Company name	TE	PTE	VRS	TE	PTE	VRS	TE	PTE	VRS
Industrial chain: technical support and information transmission									
Bai shi Tong	0.259	1	drs	0.329	0.854	drs	0.319	1	drs
Le Shi	0.2	0.311	irs	0.175	0.182	irs	0.279	1	drs
Hua Shu	1	1	–	1	1	–	0.127	0.481	drs
Jia Chuang	0.62	0.851	irs	0.669	0.881	irs	0.329	0.525	irs
Tian Wei	0.129	0.145	irs	0.13	0.138	irs	0.137	0.142	irs
Ge hua	0.067	0.361	drs	0.052	0.365	drs	0.063	1	drs
Mean	0.379	0.611		0.393	0.57	0.209	0.691		
Industrial chain: production and distribution									
Xin Wen Hua	0.39	0.464	irs	0.988	1	drs	0.981	1	drs
Hua Ce	0.609	0.624	drs	0.414	0.633	drs	0.434	0.743	drs
Hua Yi	0.283	0.446	drs	0.299	0.535	drs	0.22	0.452	drs
Guang Xian	1	1	–	0.336	1	drs	0.591	1	drs
Hua Lu	0.586	0.618	irs	1	1	–	1	1	–
Mean	0.574	0.63		0.607	0.834		0.645	0.839	
Industrial chain: channels and network operations									
Dian Guang	1	1	–	0.582	1	drs	0.527	1	drs
Zhong Shi	0.886	0.965	irs	0.928	0.941	irs	0.88	0.907	irs
Hubei Guangdian	0.902	0.949	irs	1	1	–	0.626	0.649	irs
Guangdian Net	0.44	0.451	irs	0.513	0.533	drs	0.457	0.562	drs
Ji Shi	1	1	–	1	1	–	1	1	–
Mean	0.846	0.873		0.805	0.895		0.698	0.824	
Average	0.599	0.705		0.602	0.766		0.517	0.785	

Note TE technical efficiency from CRS DEA; *PTE* technical efficiency from VRS DEA; *SE* scale efficiency; *drs* decreasing returns to scale; *irs* increasing returns to scale; *Average* the film and television industrial average

8.3.2 Constructing the Input and Output Indexes

Generally, we must give full consideration about the authenticity, comparability, maneuverability and representative when choosing input and output indexes. And input indexes often are "cost-based" indicators, such as the scale of human resources, capital, resources, infrastructure, etc. "Utility-type" indicators are more used to evaluate the efficiency, such as income, profits and the amount of growth, etc. Thus this paper uses the annual total wages, total assets (debt plus equity), fixed assets, these three indicators as the input indexes to evaluate the human investment, funding investment and material input of each company. And use the main business income and net profit as output indexes to evaluate the comprehensive profitability of each listed companies. Then calculate by DEAP2.1 software and get the results (see Table 8.1 and Fig. 8.1).

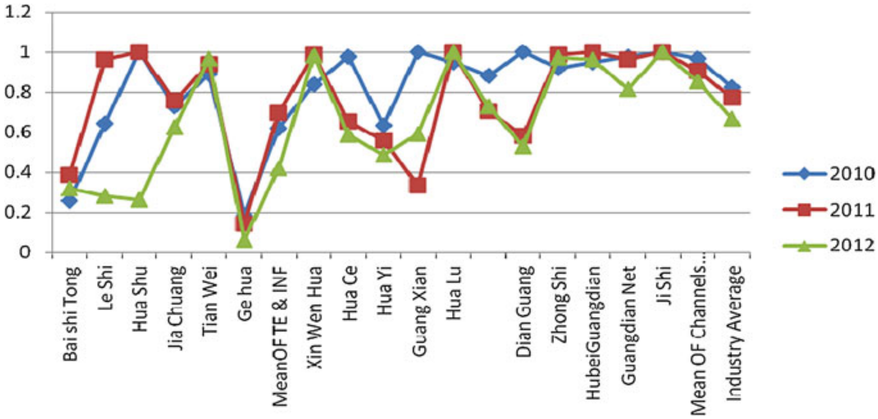

Fig. 8.1 The SE of listed companies from 2010 to 2012

8.3.3 Technical Efficiency Analysis

Technical efficiency reflects the maximum output capacity of each DMU with a given situation, the higher technical efficiency, the better technology and resources comprehensive integration capabilities.

In Table 8.1, the technical efficiency of technical support and information transmission was decreased volatility. From 0.379 in 2010, with a slight increase to 0.393 in 2011, then dropped to 0.209 in 2012, it fell as much as 46.7 % compared with 2011. The reason is that Hua Shu media has reached the technical valid for two consecutive years in 2010 and 2011. At the year of 2012, its technical efficiency decreases rapidly due to the "Triple play", seriously affected the technical efficiency of the whole industrial chain. Other companies' technical efficiency is generally not high except Jia Chuang, the technology investment and technological innovation is not enough in the technical support and information transmission industry. The overall average relative technology efficiency isn't high because of the large gap between different companies.

The technical efficiency continues to grow at the program production and distribution part, technology has an obvious effect on propelling the economic benefits. The Enlight Media and Hua Lu Baina both are effective in technology. Technical efficiency of the new culture grew fast from 0.390 in 2010 to 0.981 in 2012.

The technical efficiency of channels and network operations is decreased volatility, but the overall technical efficiency level at this part is better. Ji Shi media's technology is effective for three consecutive years; the technical efficiency of Guang Dian Net is the minimum.

The technical efficiency of the whole film and television industry is decreased volatility. From 0.599 in 2010, rose to 0.602 in 2011, dropped to 0.517 in 2012 with a decline of 13.8 %. Although the technical efficiency of production and distribution part grew rapidly, the lagging development of technical efficiency in technical support and information transmission part is seriously affecting the whole level of technical efficiency in film and television industry.

8.3.4 Pure Technical Efficiency Analysis

Pure technical efficiency reflects the effectiveness scale of pure technical factors with a certain cases of pure technical factors; the higher pure technical efficiency indicates the better utilization of technology.

The pure technical efficiency of technical support and information transmission is fluctuating growth. It decreased from 0.611 in 2010 to 0.57 in 2011, but increased to 0.691 in 2012. Besides Tian Wei video, the other five companies are all reached pure technology effectively in the past three years. But the PTE isn't volatile; Hua Shu media's pure technical efficiency had ever declined as high as 48.1 %, while Gehua had increased more than 200 %.

At the production and distribution part, pure technical efficiency grows rapidly, which has increased 133 %. Specifically, the Enlight Media maintain pure light media technology effectively for three consecutive years; Xin Wenhua and Hualu Baina both have reached effective pure technology in 2011 and 2012. The whole pure technical efficiency of production and distribution part is high; technology is adequate in this part.

The pure technical efficiency of channels and network operators is steady growth. Dian Guang media and the Ji Shi media maintain effective pure technology for three consecutive years, and Hubei Guangdian reached effective pure technology in 2011; but Guangdian Net has been the lowest in the industry. But the PTE of channels and network operators is sustained and stable developed.

In a word, the whole pure technical efficiency of film and television industry keeps on growing steadily from 2010 to 2012. Production and distribution part has the absolute advantage of technological resources with the fastest growing. The PTE of the other two industrial parts is growing slowly.

8.3.5 Scale Efficiency Analysis

Scale efficiency reflects whether the decision-making unit is doing business under the best investment scale.

At the technical support and information transmission part, scale efficiency is decreased volatility, rising from 0.618 in 2010 to 0.698 in 2011, and then dropped to 0.42 in 2012. Among the six companies, Hua Shu media achieved the best scale effect in 2010-2011, Jia Chuang video and Tian Wei video continue to develop steadily.

The scale efficiency of Le TV and Hua Shu media is volatility from 2011 to 2012, while Gehua isn't performing well with a poor economic scale (see Fig. 8.1).

The scale efficiency of program production and distribution is lower volatility, which dropped by 19.6 % between 2010 and 2011. Enlight Media has achieved the best economic scale in 2010, but its SE is volatility in these 3 years; and Hualu Baina reached the best from 2011 to 2012. In contrast, Xin Wenhua keeps a better scale efficiency; while the scale efficiency of Huayi Brothers and Huace isn't scooped enough, and still need to be improved.

At the Channels and network operation part, scale efficiency is small decreased. The scale efficiency of Dian Guang media is continuously declined; Zhong Shi media, Hubei Guangdian and Ji Shi media these three companies keep on increasing. Ji Shi media achieved the best economic scale for three consecutive years, only Guang Dian Net is continuously declined in the past three years.

The whole scale efficiency of film and television industry is continuously declined in the past three years, Decreased from 0.822 in 2010 to 0.761 in 2011, then down to 0.668 in 2012. The main reason is that the scale efficiency of each industrial part isn't performing well, which lead to a vulnerable poor scale efficiency of the most listed companies in film and television industry. In this context, mainly analyzes the scale efficiency of film and television industry in 2012 (see Table 8.2), and get the following conclusions:

1. The number of all the listed companies reached effective scale efficiency is 12.5 % in 2012, namely only Ji Shi Media and Hualu Baina has achieved the best scale efficiency. The whole scale efficiency of Chinese film and television industry is poor. There are two reasons: one is the impact of technological development. Especially the "triple play" leads to the intersection of three kinds (TV network, communication network and the internet) of business integration. This intersection makes the audience differentiation, and the new forms of Internet TV, mobile TV and other new media has attracted a large number of younger audiences. Another is that derivative products are inadequate; it's difficult to make the synergies chain works perfectly.
2. Between the three parts of the Chinese film and television industrial chain, the scale efficiency of production and distribution, channels and network, is much better than technical support and information transmission part. Because the government has opened the film and television program production market to private and foreign-funded enterprises, many investment institutions and production agencies have participated in the production market, showing a diversity of the market to ensure the richness of the programs and contents, enliven program production market. In addition, in the background of the government-run station, television station and channels become a scarce resource, making them become the powerful players in the program aired with the absolute right. While the scale efficiency of technical support and information transmission is deeply affected by "triple play".

Table 8.2 The total assets, scale efficiency and variable return to scale of listed companies in 2012

Stock	Company name	Position in the industrial chain	Total assets	SE	Variable return to scale
601929	Ji Shi	Channels & Net	553,787	1	–
300291	Hua Lu	Produce & Distribute	109,000	1	–
300336	Xin Wen Hua	Produce & Distribute	103,122	0.981	drs
600088	Zhong Shi	Channels & Net	185,950	0.971	irs
000665	HubeiGuangdian	Channels & Net	324,130	0964	irs
600831	Guangdian Net	Channels & Net	400,048	0.813	drs
300264	Jia Chuang	Te & Inf	63,643.6	0.626	irs
300251	Guang Xian	Produce & Distribute	215,684	0.591	drs
300133	Hua Ce	Produce & Distribute	176,728	0.584	drs
009017	Dian Guang	Channels & Net	1,335,760	0.527	drs
300027	Hua Yi	Produce & Distribute	413,794	0.478	drs
600637	Bai Shi Tong	Te & Inf	388,290	0.319	drs
300104	Le Shi	Te & Inf	290,116	0.279	drs
000156	Hua Shu	Te & Inf	338,357	0.264	drs
002238	Tian Wei	Te & Inf	196,873	0.142	irs
600037	Ge hua	Te & Inf	1,042,770	0.063	drs

Note SE scale efficiency; *drs* decreasing returns to scale; *irs* increasing returns to scale

8.3.6 VRS Analysis

The variable return to scale reflects the trend towards an effective decision-making unit returns to scale when scale reward is invalid. Increasing return to scale means that too little investment leads to a poor overall efficiency, so increase investment is needed to improve overall efficiency. Decreasing returns to scale means that the decision-making unit is in the situation of input redundancy and poor resource utilization efficiency, reducing the level of investment to improve efficiency is needed. As to the whole scale efficiency of Chinese film and television industry, the scale is showing a decreasing trend.

In technical support and information transmission part, the VRS of four companies is in increasing return status except Bai Shitong and Gehua, Hua Shu media has reached optimal combination during this period. In 2012, Letv and Hua shu media both have entered the state of decreasing returns to scale. As a result, the whole returns to scale efficiency of this industry chain shows a decreasing trend, indicating a serious redundancy in the Chinese film and television industry, resource utilization is not high.

The VRS of production and distribution shows decreasing returns to scale, and the input redundancy is outstanding. Enlight media achieved the best combination input and output in 2010; while the new culture is in a state of scale increasing returns, investment of resources is inadequate. Hualu Baina also achieved the best state of input–output and its reasonable resource utilization is efficiency from 2011 to 2012;

however, other companies in the same industrial chain are in the decreasing returns to scale state, which leads to a low output of the whole industry.

At the channels and network operation part, the VRS has no obvious changes or improvements. Ji Shi media has maintained the best status and keep high resource utilization for three years. The VRS of Dian Guang media and Hubei Guangdian is increasing return to scale, namely input is inadequate; Dian Guang media and Guangdian Net is in the diminishing returns. As you can see (in Table 8.1), the whole VRS of Chinese film and television industry decreased significantly from 2010 to 2012. In Table 8.2, the number of companies who achieved the effective returns to scale is 12.5, 25 % of listed companies in the state of increasing returns to scale, 62.5 % of listed companies is decreasing returns to scale, indicating that input redundancy issues of Chinese film and television industry is outstanding. Further to analyze slack variables (the number of input–output redundancy) data from 2011 to 2012, we can get the following two conclusions:

1. At the technical support and information transmission, channels and network operators parts, fixed assets, total assets, total wages and other input indicators all are redundant input. The reason, one is our country's long-term system of practice "institutions with corporate management" in Chinese film and television industry. The government puts much emphasis on "political tongue throat" and the need for ideological control of the media, state-run monopoly management system leads to a low resource utilization; the cost consciousness of the listed companies is not strong. Another reason is decide by its industrial nature. They both belong to the high investment industry, huge equipment investment is needed, and high barriers is existed when to entry and exit with a long payback period, asset specificity and high sunk costs.
2. At the production and distribution part, the technical efficiency and pure technical efficiency have maintained a good development for the past three years, input and output is reasonable, but the VRS of the industrial chain is decreasing returns to scale, which suggests that the industrial management, external environment and other factors have hindered the industry economic benefits. The reason is that the production and distribution is the non-state monopoly parts of industry chain, so the TE and PTE of private enterprises all rare good, such as Enlight Media, Huayi Brothers. But under the background of state-run TV station, television channels was created as the key position in distribution, which makes the private listed companies develop more difficultly. The difficulty for private enterprises to survive reflected in two aspects: First, the allocation of TV content resources is irrational with the wasted internal television program production resources, while private television program producers is in weakness status of the industrial chain. Second, the allocation of TV channel resource is not reasonable. This is mainly because of the television channel resources are completely in the hands of state, private economic isn't allowed to intervention, the policy making the private production agency is developed difficultly (Table 8.3).

Table 8.3 The slack variables from 2011 to 2012 (unit: Million, RMB)

Stock No.	Company name	DMU	S_1^-	S_2^-	S_3^-	S_1^+	S_2^+	DMU	S_1^-	S_2^-	S_3^-	S_1^+	S_2^+
Te & Inf													
600637	Bai Shi Tong	17	0	51,953	285	13,139	0	33	0	0	0	0	0
300104	Le Shi	18	0	6,546	6	2,576	0	34	0	0	0	0	0
000156	Hua Shu	19	0	0	0	0	0	35	51,334	0	2,016	0	0
300264	Jia Chuang	20	0	37,532	132	888	0	36	0	5,201	98	0	1,196
002238	Tian Wei	21	6,342	0	519	0	0	37	6,188	0	647	0	0
600037	Ge hua	22	171,749	32,507	0	0	18,897	38	0	0	0	0	0
Produce & Distribute													
300336	Xin Wen Hua	23	0	0	0	0	0	39	0	0	0	0	0
300133	Hua Ce	24	0	0	91	12,541	0	40	524	0	154	4,571	0
300027	Hua Yi	25	4,375	0	0	0	0	41	10,269	0	0	0	0
300251	Guang Xian	26	0	0	0	0	0	42	0	0	0	0	0
300291	Hua Lu	27	0	0	0	0	0	43	0	0	0	0	0
Channels & Net													
009017	Dian Guang	28	0	0	0	0	0	44	0	0	0	0	0
600088	Zhong Shi	29	0	83,289	157	0	2,261	45	0	42,283	0	45	3,268
000665	Hubei Guangdian	30	0	0	0	0	0	46	25,381	3,765	0	33,394	0
600831	Guang dian Net	31	70,813	0	3,405	0	0	47	92,762	0	3,545	0	0
601929	Ji Shi	32	0	0	0	0	0	48	0	0	0	0	0

Note S_1^-, S_2^-, S_3^- is the input redundancy of fixed assets, total assets, and total wages; S_1^+ and S_2^+ are the insufficient rate of main business income and net profit

8.4 Conclusions and Policy Suggestion

Through the analysis of input–output efficiency of listed companies based on CCR and BCC model in Chinese film and television industry from 2010 to 2012, we can get the following conclusions:

1. The technical efficiency of Chinese film and television industry is declined in fluctuation; and the development direction of its technical efficiency exist some differences in the each part of the industrial chain. At the technical support and information transmission part, channels and network operator part, their technical efficiency shows a reverse development compared with the production and distribution part. Although the technical efficiency grows very fast in the production and distribution part, the sluggish development of technical efficiency in the technical support and information transmission part has already seriously affected the whole level of technical efficiency in Chinese film and television industry.
2. The pure technical efficiency of the whole industry is steady growth, in terms of each industrial chain part; the growth rate of the pure technical efficiency is too different. The PTE of technical support and information transmission, channel and network operations, both are growing slowly, but the latter is much better. The PTE of production and distribution part is growing faster, which possesses the absolute technological resources.
3. The scale efficiency of the whole industry is showing a decreasing trend. The SE of each industrial chain part has fallen slightly. The lower resource utilization is outstanding in technical support and information transmission part and channel and network operations part; while economic benefit needed to be improved in the production and distribution part under the background of state-run station.

As we all know, the DMU called DEA non-integrated, whose PTE or SE both are invalid, so the further development of Chinese film and television industry must rely on two ways: One is grasping technology chances and strive to improve the comprehensive technical efficiency, especially paying more attention to the technical support and information transmission technology, focus on the layout of core resources and human resources training, increase the use efficiency of innovation resources; Another way is to grasp the economic efficiency, improving the operation and management, optimizing the allocation of resources, and enhance the economic efficiency.

Enhancing the scientific and technological strength, optimizing resource integration. Film and television industry is an information technology; it's a media which is looked as a carrier of cultural symbols and ideas for the content. Only in the process of optimizing technical level, that can provide a way of better experience and more perfect rendering method with a better way to transmit Chinese cultural elements and cultural creativity to the audience. And achieve the high integration of function and technology, economy and culture. Especially under the background of triple play, these listed companies must understand and grasp the technology development trends of real-time mobile TV, Internet TV, mobile TV and other new media, fully focused on the whole process like production and marketing, paying attention to the layout of core resources and promoting the efficiency of scientific and technological innovation. Enterprises should make efforts to improve the capacity for independent research and development of the core technology to achieve self-breakthrough, mastering the core technology. Establish and improve the personnel training mechanism, cultivating compound talents, forming a technological innovation system that the whole society to participate in, including the government, enterprises, schools, research institutions. The technological innovation system is a combination of TV technology supply based on market demand to adapt the trend of triple play.

To improve the management and resource utilization. On the one hand, continue to carry out the policy of government dominated for film and television industry. On the basis of full understanding of the market, actively promote the combination of cross-industry, cross-regional mergers, establishing industrial group to improve scale efficiency and accelerate the media integration. On the other hand, continue to promote the two-track reform in Chinese film and television industry. Through capital operation, state-owned film and television companies authorized management to establish a modern enterprise management system, clear the responsibilities of its corporate rights institutions, decision-making bodies, regulators and operators, improving the state-owned supervision and management system to achieve the goals of planning management, scientific decision-making, and rational production. And it's good for stimulating the market consciousness and market dynamics under the background of state-run station.

Improving the market mechanism, stimulating market activities and promoting the scale efficiency. Establish policy support for private enterprises to create a better atmosphere for production and distribution private enterprises to survival, such as using the experience of South Korea's development, building programs quota system to create conditions for the independent producers. Improve the marketing mechanism; actively explore the online distribution channels such as Internet TV, mobile TV, Internet cinema and other emerging online distribution channels. Make full use of new micro-channel marketing tools, like Wei Xin and Weibo, to improve product marketing. At the same time, pay attention to the development of derivative products, such as audio and video products, catering, tourism and clothing etc, perfecting the industry chain and building multi-channel, diversified source of profits.

Acknowledgments We gratefully acknowledge the research support received from the National Natural Science Fund (No. 71173150), the Key Project of the National Social Science Fund (No. 12AZD018), Program for New Century Excellent Talents in University (No. NCET-12-0389) and the key project of System Science and Enterprise Development Center of Sichuan Province (No. XQ12A01).

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Chapter 9
A Balanced Transfer Learning Model for Customer Churn Prediction

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Abstract Class imbalance presents significant challenges to customer churn prediction. Most of previous research efforts addressing class imbalance focus on the usage of in-domain information. In fact, due to the development of information technology, customer data of related domains may be gathered. These data come from different time-periods, districts or product categories. In this paper, we develop a new churn prediction model based on transfer learning model, which uses customer data from related domains to address the issue of data imbalance. The new model is applied to a real-world churn prediction problem in the bank industry. The results show that the new model provides better performance than traditional method such as resampling and cost-sensitive learning in dealing with class balance.

Keywords Customer churn prediction · Transfer learning · Class imbalance

9.1 Introduction

Due to the globalization of marketplace, the business environment of the credit card industry is characterized by fierce competition and saturated markets in the past few years. In this context, more and more banks realize that their most precious asset is the existing customers and customer retention or customer churn prevention has become the source of core competence. Therefore, a small improvement in customer retention can lead to a significant increase in profit.

Customer churn prediction is able to detect possible churner before they leave the company and companies' interest in churn prediction has substantially increased over the years [1]. Churn is often a rare object [7]. There are usually very few churners as compared to the large number of non-churners, which is called class imbalance

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_9,

from the perspective of classification. Class imbalance brings great challenge to churn prediction. Most of existing learning algorithms assume a relatively balanced data distribution. As a result, they tend to classify all customers as belonging to the majority class (non-churner), resulting in high overall precision but unacceptably low accuracy with respect to the minority class (churner). This would be useless at detecting the churner, which is the customer group of interest. Indeed, the problem of learning over imbalanced datasets are recently designated as one of the ten challenging problems in data mining research [8].

In order to solve the problem of class imbalance, two categories of techniques have been developed [6]. First, there are data level (external) techniques which add preprocessing steps to re-balance the data distribution. Second, there are algorithm level (internal) approaches which use various forms of cost adjustment to adapt existing classifier learning algorithms to bias toward the minority class. Both types of techniques have their own advantages and disadvantages. Nevertheless, all the previous research efforts only focus on the usage of in-domain information and there is no increase of knowledge. The improvement of prediction accuracy in the minority class incurs the deterioration in the majority class.

In marketing practice, abundant customer data from related domains are often available. For example, customer data for a same objective may have been gathered in the earlier time or in other areas. Clearly, the data from related domains may provide valuable information to enhance the model performance for churn prediction in the domain of interest (hereafter, referred to as the target domain). So, it is an interesting research issue to utilize the information provided by the auxiliary customer data to alleviate the problem of class imbalance. Transfer learning provides an effective way to solve the above problems. Transfer learning is a newly developed technique in the field of machine learning in recent years, it has already been successfully applied in the field of artificial intelligence, text mining, image processing [5]. However, it has not yet been introduced into the field of customer relationship management, especially customer churn prediction with class imbalance.

In our study, we investigate how we can better handle class imbalance in churn prediction by using transfer learning. We develop a new balanced transfer learning model (BTL) based on ensemble technique TrBagg [3], which incorporates information related information from different time-period. Traditionally, people create a model for the churn prediction without considering these out-dated data. Some behavior patterns of churner may repeated despite the variation of economic environment, so the out-dated customer data may contain some common customer patterns. Hence they can be of help in training the churn prediction model. However, the out-dated customer data have a different data distribution. The main contribution of this paper is to show how the related information from different time-period can be incorporated in the process of churn prediction, where the nature of the relation is unknown. The research results provide a new way to solve the class imbalance problem in customer churn prediction.

The remainder of this paper is organized as follows. In Sect. 9.2, we describe in detail the proposed new approach. Section 9.3 applies the proposed methodology to a real-world churn prediction problem in credit card industry. Section 9.4 gives conclusions and directions for further research.

9.2 Transferred Churn Prediction

In customer churn prediction, one attempts to create a model that predicts weather a customer will churn. Suppose we have a data set D with n observations $D = \{(\mathbf{x}_i, y_i)\}_{i=1}^{n}$. The dependent variable $y_i \in \{1, \cdots, p\}$ indicates customer's state. It has two values, 0 represents the non-churner, and 1 represents the churner. A d-dimensional feature vector, $\mathbf{x}_i \in R^d$, describes the customers. The objective of churn prediction is to learn a model f that predicts the state of each observation y_i correctly with feature vector $\mathbf{x}_i$. In the past few decades, numerous successful approaches to churn prediction have been developed.

However, due to time and budget constraints, only a few observations are churner in the dataset. which make churn prediction problematic. Fortunately, there are often plenty of auxiliary churner from the related domain (source domain). We denote the data set in the target domain by $D_T = \{(\mathbf{x}_i^T, y_i^T)\}_{i=1}^{n}$ and the source data set by $D_S = \{(\mathbf{x}_i^S, y_i^S)\}_{i=1}^{m}$, where m is the number of customers in the source domain and $\mathbf{x}_i^S \in X^d$. The question now is whether we can use the information from the auxiliary data to better tackle churn prediction in the above-mentioned situation.

To solve the above problem, a new choice modeling method based on TrBagg is presented in our study. TrBagg is an algorithm of transfer learning developed by Kamishima et al. [3], which modifies the well-known bagging model. TrBagg augments the performance of the models in the target domain by aggregating the base models that are built on data sets that incorporate data from the source domains. TrBagg assumes that the models learned from useful data for the target domain will accurately discriminate the given target data. TrBagg selects these useful base models and combines them to form an aggregated model. The presented BTL is similar to TrBagg and it uses a bootstrap sampling on both the source and target data to obtain multiple data subsets for the training of base models. However, BTL introduces only the minority class instances from the source domain, which is different from TrBagg and the other algorithms. In addition, the base model selection in TrBagg depends on the overall accuracy. Because the target data are unbalanced, such a selection mechanism is questionable, and a cost-sensitive voting mechanism is proposed to address this issue.

The details of the new model are described as follows:

Step 1. Divide the data from the target domain into the minority data set P^T and majority data set N^T. Similarly, the observation from the source domain are all from the minority class, So $P^S = D_S$.

Step 2. Randomly sampled a data set $\hat{P}_i$ from $P^S \cup P^T$ with replacement, $|\hat{P}_i| = |N^T|$ to obtain a balanced training data set $\hat{D}_i$.

Step 3. Learning a base classifier f^i from this training set $\hat{D}_i$ by using an arbitrary classification algorithm.

Step 4. Calculate the value of the cost weighted overall accuracy (CWOA) on the original target dataset D^T for each model f^i as follows: $CWOA = (C_N * TNr + C_P * TPr)/(C_N + C_P)$, where C_N and C_P are the misclassification cost of the majority and minority class, respectively. TNr and TPr are the percentages of correctly predicted customers for the majority and minority class,respectively.

Step 5. Repeat Step 2–4 to get K candidate base learners $\{f^1, f^2, \cdots, f^K\}$.

Step 6. Using CWOA as the weight to produce the final aggregated model, $f^A = G(f^1, f^2, \cdots, f^K)$.

9.3 Empirical Study

This section applies the proposed methodology to a real-world churn setting.

1. Data

To evaluate the performance of the proposed method, we applied it to a real-world database. We studied the data on customers of a major commercial bank of Chongqing province of China. In this study, data collected in December 2010. In this study, we considered two kinds of variables: personal demographics, and transactional variables Personal demographics we considered in this study include gender, education, income and employment type. All the 25 predictors are given in Table 9.1. Here we defined churner as the customers who cancel the card or do not have transactions in three consecutive months. We collected from the bank information system and get 1,790 customers from 2008, the churn rate is 7.35 %. Fortunately, the bank also stores the information of 108 churners in the system before 2008, which will be used as the auxiliary data.

The target data set was split into training (70 % of the observations) and test sets (30 % of the observations). The training set is used for model building, while the test set allows for valid assessment of performance [4]. The data division was performed in a stratified manner to ensure that the proportions of churner were the same in both the training dataset and the testing dataset. The class variable of the dataset is heavily skewed: the number of churners is much smaller than the number of non-churners. In order to validate the effectiveness of the proposed method, we compared it with some other benchmark method in churn prediction: Support Vector Machine (SVM) and Artificial Neural Network (ANN). For both methods, we all considered five experimental scenario: Firstly, we directly used SVM and ANN modeling without considering the class imbalance; Secondly, we used random under sampling (RUS) to get a random sample of non-churners so that there are the same number of churners and non-churners in the dataset. Thirdly, over sampling technology SMOTE [2] was

Table 9.1 Variables used for churn prediction

Number	Name
Transactional variable	
X_1	Total number of consumption
X_2	Total amount of consumption
X_3	Total number of cashing
X_4	Customer survival time
X_5	Customers' total contribution
X_6	Customers effective survival time
X_7	Average amount of the proportion of
X_8	Whether the associated deduction
Transactional variable	
X_{10}	Number of consumption in the last month
X_{11}	Number of consumption in the last two month
X_{12}	Number of consumption in the last three month
X_{13}	Number of consumption in the last four month
X_{14}	Number of consumption in the last five month
X_{10}	Number of cashing in the last month
X_{11}	Number of cashing in the last two month
X_{12}	Number of cashing in the last three month
X_{13}	Number of cashing in the last four month
X_{14}	Number of cashing in the last five month
X_{10}	Weather overdue in the last two month whether
X_{11}	Proportion of the amount of use/historical average proportion in the last month
X_{11}	Proportion of the amount of use/historical average proportion in the two month
Geographic information	
X_{11}	Gender
X_{11}	Income
X_{11}	Industry
X_{11}	Education level

used to increase the number of churners to achieve a balanced dataset; Fourth, we considered the usage of cost-sensitive learning method. Fifthly, we directly combined the source and target data without considering the difference.

For the SVM method, we choose the radial basis function as kernel function. We used the most commonly used back propagation algorithm to train multi-layer artificial neural network. The number of hidden nodes was set to be 10 while the number of iterations was set to 500. To deal with the class balance, we considered both sampling methods and cost-sensitive methods. Random undersampling and SMOTE were exploited in the paper. For SMOTE, we considered three different sample proportion (100, 200 and 300 %). Both random under sampling (RUS) and SMOTE sampling were repeated five times to avoid accident error. All the methods were implemented by using Matlab. In this study, we use the overall accuracy, Area Under the Receiver Operating Characteristic Curve (AUC) and Type I and Type II error to measure the performance of the models.

Table 9.2 Comparison with ANN based benchmark methods

Method	Accuracy	AUC	Type-I	Type-II
ANN	92.03	80.24	22.50	97.57
ANN+RUS	87.68	83.57	77.50	88.49
ANN+SMOTE ($\alpha = 100\ \%$)	91.33	82.69	55.00	92.22
ANN+SMOTE ($\alpha = 200\ \%$)	90.23	86.41	75.00	91.44
ANN+SMOTE ($\alpha = 300\ \%$)	89.10	86.54	72.50	90.42
Cost-ANN ($C_2 = 3$)	91.30	83.11	62.50	93.59
Cost-ANN ($C_2 = 5$)	90.39	84.34	77.50	91.42
Cost-ANN ($C_2 = 7$)	86.86	87.42	85.00	87.01
ANN-A	88.58	82.15	65.00	90.51
TAC	92.28	90.43	90.50	92.42

Table 9.3 Comparison with ANN based benchmark methods

Method	Accuracy	AUC	Type-I	Type-II
SVM	93.63	80.30	30.00	98.69
SVM+RUS	86.55	83.93	80.00	87.07
SVM+SMOTE ($\alpha = 100\ \%$)	89.76	84.65	57.50	92.33
SVM+SMOTE ($\alpha = 200\ \%$)	89.02	86.10	75.00	90.13
SVM+SMOTE ($\alpha = 300\ \%$)	88.64	88.11	72.50	89.92
Cost-SVM ($C_2 = 3$)	91.64	84.52	60.00	94.16
Cost-SVM ($C_2 = 5$)	91.84	83.19	80.00	92.78
Cost-SVM ($C_2 = 7$)	86.75	87.50	87.50	86.69
SVM-A	89.09	83.43	62.50	91.23
TAC	92.28	90.43	90.50	92.42

2. Experimental Results

Tables 9.2 and 9.3 shows the predictive performance of all the methods implemented in the experiments. It can be seen from Tables 9.2 and 9.3.

(1) Although direct using of ANN and SVM methods can achieve a higher overall classification accuracy, but we can seed that the prediction accuracy for churners is very low (22.50 and 30.00 %), which indicates that the class imbalance have a negative impact on churn prediction; (2) When using the RUS sample, we can see that both the ANN or SVM has significantly improved over prediction accuracy of the churned customers. But at the same time, the classification accuracy of the non-churners has significantly decreased. this is mainly because we have discarded a large number of samples of non-churners in RUS; (3) When SMOTE sampling was used, the accuracy of non-churners has also been significantly improved, but improvement is smaller than RUS sampling, while classification accuracy of non-churner is also higher than the RUS sample. On the other hand, with the prediction accuracy of churners does not monotonically increases as the sampling proportion; (4) When we use of cost-sensitive learning, we can see that the prediction accuracy of

churners increase with the misclassification cost while the accuracy of non-churners and overall accuracy decreases; (5) Direct combination of source and target data. We can see this strategy will improve the classification accuracy of the churners to certain extent, but the results are still not very satisfactory. This is mainly because with the company's business development, the characteristics of churner in the target areas has changed; (6) We can see BTL gives the best AUC value and prediction accuracy churners. At the same time the prediction accuracy is also satisfactory. To sum up, Sampling method (under-sampling and over-sampling) and cost sensitive learning can help us to eliminate the negative impact of class imbalance to a certain degree. But these two methods only use the information within the system. The improve is at the expense of non-churner. However, the new method proposed in this paper BTL not only gives the prediction accuracy of churners but also non-churners.

9.4 Conclusion

Class imbalance is an challenging issue in customer churn prediction. Most previous research attempt to use in domain information to address this issue. In our study, a new solution based on external information is proposed to deal with class imbalance in churn prediction. We investigate how to make full use of data from related domains. We have shown how transfer learning techniques can be used to explore the potential of the proposed approach as a tool used to handle the class imbalance in the churn prediction. The new model help companies discover valuable churners. In the future, we will consider to introduce multiple source domain data to the target domain instead of single domain transfer in this paper.

Acknowledgments This work is supported by National Natural Science Foundation of China (Grant No. 71071101 and No. 71172196) and Scientific Research Starting Foundation for Young Teachers of Sichuan University (2012SCU11013).

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Chapter 10
Assessment Employee Empowerment Through Combination of FAHP and VIKOR Methods

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Abstract Nowadays challenging world of business forces managers to evaluate which factors are crucial for their organization continuousness. One of the most important competitive advantages is employee empowerment. The aim of this study is applying a model to rank bank branches by consider the main influence factors that affect employee empowerment. Proposed approach is based on Fuzzy Analytic Hierarchy Process (FAHP) and VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) methods. FAHP method is used in determining the weights of the criteria by decision makers and then rankings of the banks were determined by VIKOR method. The proposed method in this study is used for ranking the five branches of Agri bank in field of employee empowerment by eight indexes that have major impacts on it.

Keywords Employee empowerment · Fuzzy sets · Fuzzy analytic hierarchy process (FAHP) · VIKOR method

10.1 Introduction

Rapid technological and economic change and also increased global competition has made more attention to the empowerment of employee's issues. From 1990 it has been suggested that organizations with strong, committed, skilled and motivated employees will be able to better adapt to changes and compete with other organizations [15].

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_10,

Employees' organizational commitment is considered a critical factor which influences the employees' behavior of bringing positive benefits to an organization. Committed employees tend to be more willing to make personal sacrifices for their organizations. In addition, highly committed employees are more likely to relate themselves with the goals and values of the organization. These employees oftentimes devote extra time to work and are proud of being members of the organization. However, given increasing work redesign issues in responding to external as well as internal business environments, many organizations have tried to maintain job effectiveness and efficiency by empowering employees in order to foster more committed workers to overcome problems such as complex job features, demanding customer needs, diverse work groups, flatter organizational structures, and so on. However, employees' commitment oftentimes is sabotaged by downsizing, a business practice aimed at reducing overhead expenses with the goal of enhancing performance [12].

The modern banking system is not excluded from it and requires empowered employees to survive and continue as well as other organizations. Communication and interaction of this system with various factors such as government, private sector, financial supporters and other international banks and also Social, economic, cultural and diplomat factors has led to the creation of turbulent environment for banking system. Creation institutional capacity in the Bank can largely protect banking system against changes [15].

By using MADM techniques, this research is going to determine which factors have more influence on employee empowerment in banking system. It will use VIKOR method to rank bank branches.

10.2 Literature Review

Definitions of the nature of empowerment have fallen within a common frame in some aspects. On the other hand, despite a common frame being formed, there is no fully agreed definition of empowerment [20]. Conger and Kanungo propose that empowerment be viewed as a motivational construct-meaning to enable rather than simply to delegate. Therefore they definition of empowerment as a process of enhancing feelings of self-efficacy among organizational members through the identification of conditions that foster powerlessness and through their removal by both formal organizational practices and informal techniques of providing efficacy information [6]. The Oxford Dictionary defines empowerment as: "give (someone) the authority or power to do something, make (someone) stronger and more confident, especially in controlling their life and claiming their rights". Bowen and Lawler [2] and Carless [4] described Empowerment as a venue to enable employees makes decisions. Humborstad and Perry [10] suggest that Managers use empowerment to allow workers to solve problems themselves but they must also include actions that foster job satisfaction and organizational commitment, to ensure that empowerment would affect turnover intention among employees. Trust between employees and managers are an important contributor to goal congruence, and a determinant of both the long-term success of the organization and the well-being of its employees. Without trust, employees become self-protective and defensive. Therefore, managers need to demonstrate trust in their employees by "distributing power, exhibiting confidence in employees, providing necessary resources and accepting new ideas".

Conger and Kanungo believed that for empowerment, first, the effectiveness of the model should be tested. Specifically, the concept of self-efficacy should be further operational and tested. A more direct link between empowerment practices and leadership should be studied [6].

According to evaluation of the major dimensions in empowerment during 21th century researches it could be considered some influence factors in surveys. Tubbs and Moss found that information, authority, training, access to resources, and responsibility are the major dimensions of empowerment. Vecchio suggested clarity of goals and visions, organization belonging, cooperation as main influence factors in empowerment. Huczynski and Bachnan showed that the dimensions of empowerment are: authority, style of leadership, organizational belonging, cooperation, responsibility, and job enrichment. Rue and Byars suggested that there are two factors that are more important than other factors in empowerment and they are authority and Decentralization. Seyyed javadin and others evaluated major dimensions of empowerment since 1983 to 2003 and extracted twenty of them. By using factor analysis technique they recognized five dimensions as most important factors in employee empowerment in banking system [22]. Ogden and Others found that there are three factors that affect the empowerment: authority, attitude, and experiences of other organizational changes. They believed that the third factor of those is the most significantly dimension [16]. Men [14] showed that employees' perceptions of empowerment have impact on quality of empowerment.

10.3 Fuzzy Sets

In order to deal with vagueness of human thought, Zadeh first introduced the fuzzy set theory. A fuzzy set is a class of objects with a continuum of grades of membership. Such a set is characterized by a membership function which assigns to each object a grade of membership ranging between zero and one [25]. A fuzzy set is an extension of a crisp set. Crisp sets only allow full membership or non-membership at all, whereas fuzzy sets allow partial membership. In other words, an element may partially belong to a fuzzy set [8]. Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling: uncertain systems in industry, nature and humanity; and facilitators for commonsense reasoning in decision-making in the absence of complete and precise information. Their role is significant when applied to complex phenomena not easily described by traditional mathematical methods, especially when the goal is to find a good approximate solution [1]. Fuzzy sets theory providing a more widely frame than classic sets theory, has been contributing to capability of reflecting real world [9]. Modeling using fuzzy sets has proven to be an effective way for formulating decision problems where the information available is subjective and imprecise [26].

10.4 Fuzzy Analytic Hierarchy Process

First proposed by Thomas L. Saaty (1980), the analytic hierarchy process (AHP) is a widely used multiple criteria decision-making tool. The analytic hierarchy process, since its invention, has been a tool at the hands of decision-makers and researchers, becoming one of the most widely used multiple criteria decision-making tools [23]. Although the purpose of AHP is to capture the expert's knowledge, the traditional AHP still cannot really reflect the human thinking style [11]. The traditional AHP method is problematic in that it uses an exact value to express the decision maker's opinion in a comparison of alternatives [24]. And AHP method is often criticized, due to its use of unbalanced scale of judgments and its inability to adequately handle the inherent uncertainty and imprecision in the pairwise comparison process [7]. To overcome all these shortcomings, fuzzy analytical hierarchy process was developed for solving the hierarchical problems. Decision-makers usually find that it is more accurate to give interval judgments than fixed value judgments. This is because usually he/she is unable to make his/her preference explicitly about the fuzzy nature of the comparison process [11]. The first study of fuzzy AHP is proposed by Laarhoven and Pedrycz [13], which compared fuzzy ratios described by triangular fuzzy numbers. Buckley [3] initiated trapezoidal fuzzy numbers to express the decision makers evaluation on alternatives with respect to each criterion Chang [5] introduced a new approach for handling fuzzy AHP, with the use of triangular fuzzy numbers for pair-wise comparison scale of fuzzy AHP, and the use of the extent analysis method for the synthetic extent values of the pair-wise comparisons. Fuzzy AHP method is a popular approach for multiple criteria decision-making. In this study the extent fuzzy AHP is utilized, which was originally introduced by Chang [5]. Let $X = \{x_1, x_2, x_3, \cdots, x_n\}$ an object set, and $G = \{g_1, g_2, g_3, \cdots, g_n\}$ be a goal set. Then, each object is taken and extent analysis for each goal is performed, respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$\widetilde{M}_{g_i}^1, \widetilde{M}_{g_i}^2, \cdots, \widetilde{M}_{g_i}^m, \quad i = 1, 2, \cdots, n, \tag{10.1}$$

where $\widetilde{M}_{g_i}^j (j = 1, 2, 3, \cdots, m)$ are all triangular fuzzy numbers. The steps of the Chang's [5] extent analysis can be summarized as follows:

Step 1. The value of fuzzy synthetic extent with respect to the ith object is defined as:

$$S_i = \sum_{j=1}^{m} \widetilde{M}_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} \widetilde{M}_{g_i}^j \right]^{-1}, \tag{10.2}$$

where $\otimes$ denotes the extended multiplication of two fuzzy numbers. In order to obtain $\sum_{j=1}^{m} \widetilde{M}_{g_i}^{j}$, it performs the addition of M extent analysis values for a particular matrix such that,

$$\sum_{j=1}^{m} \widetilde{M}_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right), \tag{10.3}$$

and for obtain $[\sum_{i=1}^{n} \sum_{j=1}^{m} \widetilde{M}_{g_i}^{j}]^{-1}$, it performs the fuzzy addition operation of $\widetilde{M}_{g_i}^{j}$ $(j = 1, 2, \cdots, m)$ values such that,

$$\sum_{i=1}^{n} \sum_{j=1}^{m} \widetilde{M}_{g_i}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right). \tag{10.4}$$

Then, the inverse of the vector is computed as,

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} \widetilde{M}_{g_i}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i,} \right), \tag{10.5}$$

where $u_i, m_i, l_i > 0$.

Finally, to obtain the S_j, it performs the following multiplication:

$$\begin{aligned} S_i &= \sum_{j=1}^{m} \widetilde{M}_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} \widetilde{M}_{g_i}^{j} \right]^{-1} \\ &= \left(\sum_{j=1}^{m} l_j \otimes \sum_{i=1}^{n} l_i, \sum_{j=1}^{m} m_j \otimes \sum_{i=1}^{n} m_i, \sum_{j=1}^{m} u_j \otimes \sum_{i=1}^{n} u_i \right). \end{aligned} \tag{10.6}$$

Step 2. The degree of possibility of $\widetilde{M}_2 = (l_2, m_2, u_2) \geq \widetilde{M}_1 = (l_1, m_1, u_1)$ is defined as $V(\widetilde{M}_2 \geq \widetilde{M}_1) = \sup[\min(\widetilde{M}_1(x), \widetilde{M}_2(x))]$.

This can be equivalently expressed as,

$$V\left(\widetilde{M}_2 \geq \widetilde{M}_1\right) = hgt\left(\widetilde{M}_1 \cap \widetilde{M}_2\right) = \widetilde{M}_2(d) = \begin{cases} 1, & \text{if } m_2 > m_1 \\ 0, & \text{if } l_1 > u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \text{otherwise.} \end{cases} \tag{10.7}$$

Literature [5] illustrates $V(\widetilde{M}_2 \geq \widetilde{M}_1)$ for the case d for the case $m_1 < l_1 < u_2 < m_1$, where d is the abscissa value corresponding to the highest crossover point D between $\widetilde{M}_1$ and $\widetilde{M}_2$, to compare $\widetilde{M}_1$ and $\widetilde{M}_2$, it need both of the values $V(\widetilde{M}_1 \geq \widetilde{M}_2)$ and $V(\widetilde{M}_2 \geq \widetilde{M}_1)$.

Step 3. The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1, 2, \cdots, K)$ is defined as $V(\widetilde{M} \geq \widetilde{M}_1, \widetilde{M}_2, \cdots, \widetilde{M}_K) = \min V(\widetilde{M} \geq \widetilde{M}_i),\ i = 1, 2, \cdots, k$.

Step 4. Finally, $W = (\min V(s_1 \geq s_k), \min V(s_2 \geq s_k), \cdots, \min V(s_n \geq s_k))^T$, is the weight vector for $k = 1, 2, \cdots, n$.

10.5 VIKOR Method

1. Introduction to VIKOR

The VIKOR method is a compromise MADM method, developed by Opricovic and Tzeng [17, 18] started from the form of Lp-metric:

$$L_{pi} = \left\{ \sum_{j=1}^{n} \left[\frac{\omega_j (f_j^* - f_{ij})}{(f_j^* - f_j^-)} \right]^p \right\}^{\frac{1}{p}} \quad 1 \leq p \leq +\infty; \quad i = 1, 2, \cdots, I. \tag{10.8}$$

The VIKOR method can provide a maximum "group utility" for the "majority" and a minimum of an individual regret for the "opponent" [17–19].

2. Working Steps of VIKOR Method

All papers must be in Microsoft Word format, including figures, tables and references. The file of each paper cannot be larger than 2,000 Kb. Please embellish the figures in detail more carefully. Please improve the definition of all the figures appeared in your paper with the distinguish rate as high as possible.

(1) Calculate the normalized value

Assuming that there are m alternatives, and n attributes. The various I alternatives are denoted as x_i. For alternative x_j, the rating of the jth aspect is denoted as x_{ij}, i.e. x_{ij} is the value of jth attribute. For the process of normalized value, when x_{ij} is the original value of the ith option and the jth dimension, the formula is as follows: $f_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x_{ij}^2}}, i = 1, 2, \cdots, m, j = 1, 2, \cdots, n$.

(2) Determine the best and worst values

For all the attribute functions the best value was f_j^* and the worst value was f_j^-, that is, for attribute $J = 1 - n$, it get Eqs. (10.9) and (10.10):

$$f_j^* = \max f_{ij}, \quad i = 1, 2, \cdots, m, \tag{10.9}$$

$$f_j^- = \min f_{ij}, \quad i = 1, 2, \cdots, m, \tag{10.10}$$

where f_j^* the positive ideal solution for the jth criteria is, f_j^- is the negative ideal solution for the jth criteria. If one associates all f_j^*, one will have the optimal combination, which gets the highest scores, the same as f_j^-.

(3) Compute the distance of alternatives to ideal solution
This step is to calculate the distance from each alternative to the positive ideal solution and then get the sum to obtain the final value according to equation:

$$S_i = \sum_{j=1}^{n} w_j \left(f_j^* - f_{ij}\right) / \left(f_j^* - f_j^-\right), R_i = \max_j \left[w_j \left(f_j^* - f_{ij}\right) / \left(f_j^* - f_j^-\right)\right], \tag{10.11}$$

where S_i represents the distance rate of the ith alternative to the positive ideal solution (best combination), R_i represents the distance rate of the ith alternative to the negative ideal solution (worst combination). The excellence ranking will be based on S_i values and the worst rankings will be based on R_i values. In other words, S_i, R_i indicate L_{1i} and L_{*i} of L_{p^-} metric respectively.

(4) Calculate the VIKOR values
Q_i for $i = 1, 2, \cdots, m$, which are defined as$Q_i = v\left[\frac{S_i - S^*}{S^- - S^*}\right] + (1 - v)\left[\frac{R_i - R^*}{R^- - R^*}\right]$, where $S^- = \max_i S_i$, $S^* = \min_i S_i$, $R^- = \max_i R_i$, $R^* = \min_i R_i$ and v is the weight of the strategy of "the majority of criteria" (or "the maximum group utility"). $\left[\frac{S_i - S^*}{S^- - S^*}\right]$ Represents the distance rate from the positive ideal solution of the ith alternative's achievements. In other words, the majority agrees to use the rate of the ith. $\left[\frac{R_i - R^*}{R^- - R^*}\right]$ Represents the distance rate from the negative ideal solution of the ith alternative; this means the majority disagree with the rate of the ith alternative. Thus, when the v is larger (> 0.5), the index of Q_i will tend to majority agreement; when v is less (< 0.5), the index Q_i will indicate majority negative attitude; in general, $v = 0.5$, i.e. compromise attitude of evaluation experts.

(5) Rank the alternatives by Q_i values
According to the Q_i values calculated by Step 4, it can rank the alternatives and to make-decision.

10.6 Case Study

This part tries to establish proposed model in Agri bank. In this case, researchers try to rank the five branches of Agri bank in field of employee empowerment (Branch 1, Branch 2, Branch 3, Branch 4, and Branch 5) (Fig. 10.1).

(1) Extract the most important criteria in case study and design the decision tree
In this step, it should be noted that according to case study, the important criteria should be extracted. Then the decision tree can be designed.

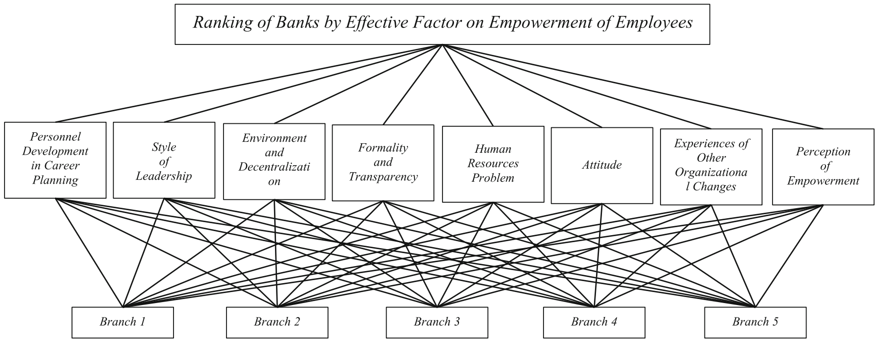

Fig. 10.1 Decision tree of case study

Table 10.1 Linguistic variables for paired comparison criteria

Equal important	1	1	1
Weakly more important	1	3	5
More important	3	5	7
Strongly more important	5	7	9
Absolutely more important	7	9	11

The most important employee empowerment criteria in Agri Bank are Personal development in career planning, Style of leadership, Environment and decentralization, Formality and transparency, Human resource's problems, Attitude, Experience of other organizational changes, and Perceptions of empowerment. The decision tree of this case study as follow:

(2) Measure the weight of each criterion by using FAHP technique.

To measure the weighting of criteria, should establish criterion paired comparison matrix according to experts of banking industry. It is better used the more than ten opinions of expert for receive more stable results. To establish criterion paired comparison matrix. To convert the fuzzy linguistic variables to fuzzy number can use the following Table 10.1.

After collecting the opinions of experts, using the arithmetic mean for construct the group paired comparison matrix (Tables 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.9, 10.10 and 10.11).

$$a_{ij}(\text{Total}) = \frac{\sum_{z=1}^{n} a_{ij}(z)}{n}, \qquad z\text{: number of expert}, \qquad a_{ij}\text{: } (L, m, u)$$

Step 1. by use the Eq. (10.8), S_i collected:

Step 2. by use the Eq. (10.9), the degree of possibility matrix as

Step 3. calculate the minimum of each row.

Step 4. the weight can be calculated of the minimum values obtained in the previous step.

Table 10.2 Total paired comparison matrix

Total	C_1			C_2			C_3			C_4		
	L	m	u	L	m	u	L	m	u	L	m	u
C_1	1	1	1	0.2	0.33	1	1	3	5	1	1	1
C_2	1	3	5	1	1	1	0.2	0.33	1	1	3	5
C_3	0.2	0.33	1	1	3	5	1	1	1	1	3	5
C_4	1	1	1	0.2	0.33	1	0.2	0.33	1	1	1	1
C_5	0.14	0.2	0.33	1	1	1	1	3	5	1	3	5
C_6	1	1	1	1	1	1	0.14	0.2	0.33	0.2	0.33	1
C_7	1	1	1	1	3	5	1	0.33	1	1	1	1
C_8	0.2	0.33	1	0.14	0.2	0.33	1	1	1	1	0.33	1
Total	C_5			C_6			C_7			C_8		
	L	m	u	L	m	u	L	m	u	L	m	u
C_1	3	5	7	1	3	5	1	1	1	1	3	5
C_2	1	1	1	1	1	1	0.2	0.33	1	3	5	7
C_3	0.2	0.33	1	3	5	7	1	3	5	1	1	1
C_4	0.2	0.33	1	1	3	5	1	1	1	1	3	5
C_5	1	1	1	1	3	5	0.2	0.33	1	1	1	1
C_6	0.2	0.33	1	1	1	1	0.2	0.33	1	1	3	5
C_7	1	3	5	1	3	5	1	1	1	0.2	0.33	1
C_8	1	1	1	0.2	0.33	1	1	3	5	1	1	1

Table 10.3 Fuzzy synthetic extent of each criterion

S_i	Lk	mk	uk
$S_1 =$	0.059	0.174	0.476
$S_2 =$	0.054	0.147	0.403
$S_3 =$	0.054	0.167	0.476
$S_4 =$	0.036	0.100	0.293
$S_5 =$	0.041	0.146	0.427
$S_6 =$	0.030	0.072	0.207
$S_7 =$	0.046	0.127	0.366
$S_8 =$	0.030	0.066	0.207

(3) Design decision matrix by consider to the scores of each bank in each criteria The decision matrix to rank the five banks is as follows. a_{ij}th are numbers in 1-10 scale that show the score of bank branch(i).

(4) Rank the banks by attention to measured decision matrix and use VIKOR method.

Step 1. Calculate the normalized decision matrix, use Eq. (10.1)

Step 2. Determine the best and worst values in each column by use Eqs. (10.2), (10.3)

Step 3. Compute the distance of alternatives to ideal solution by use Eq. (10.4), (10.5)

Step 4. Calculate the VIKOR values Q_i by use Eq. (10.6).

Step 5. Rank the alternatives

Table 10.4 Degree of possibility matrix

V	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
S_1		1.000	1.000	1.000	1.000	1.000	1.000	1.000
S_2	0.928		0.946	1.000	1.000	1.000	1.000	1.000
S_3	0.984	1.000		1.000	1.000	1.000	1.000	1.000
S_4	0.761	0.836	0.781		0.847	1.000	0.902	1.000
S_5	0.929	0.996	0.946	1.000		1.000	1.000	1.000
S_6	0.593	0.672	0.618	0.859	0.694		0.746	1.000
S_7	0.868	0.940	0.886	1.000	0.946	1.000		1.000
S_8	0.578	0.653	0.602	0.831	0.675	0.964	0.724	

Table 10.5 Minimum of each row in degree of possibility matrix

S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
1	0.928	0.984	0.761	0.929	0.593	0.868	0.578

Table 10.6 Final weight of each criterion

C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
0.151	0.140	0.148	0.115	0.140	0.089	0.131	0.087

Table 10.7 Decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Bank branch 1	7	6	8	5	3	2	5	4
Bank branch 2	4	3	5	4	4	3	3	3
Bank branch 3	5	4	7	6	6	5	2	5
Bank branch 4	6	7	6	8	5	8	4	6
Bank branch 5	5	7	6	7	4	3	6	4

Table 10.8 Normalized decision matrix

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
Bank branch 1	0.570	0.476	0.552	0.363	0.297	0.190	0.527	0.396
Bank branch 2	0.326	0.238	0.345	0.290	0.396	0.285	0.316	0.297
Bank branch 3	0.407	0.317	0.483	0.435	0.594	0.475	0.211	0.495
Bank branch 4	0.488	0.555	0.414	0.580	0.495	0.759	0.422	0.594
Bank branch 5	0.407	0.555	0.414	0.508	0.396	0.285	0.632	0.396

Table 10.9 Best and worst values in each column

Max	0.552	0.580	0.594	0.759	0.632	0.594
Min	0.345	0.290	0.297	0.190	0.211	0.297
W_j	0.148	0.115	0.140	0.089	0.131	0.087

To rank the bank branch 1, $\cdots$ bank branch 5, sort the Q_i ascending.

According to Table 10.12, Bank branch 4 is best one in field of employee empowerment.

Table 10.10 Distance of alternatives to ideal solution

	S_i	R_i
Bank branch 1	0.441	0.140
Bank branch 2	0.906	0.151
Bank branch 3	0.516	0.131
Bank branch 4	0.261	0.099
Bank branch 5	0.454	0.100

Table 10.11 Q_i values

	S_i	R_i	Q_i
Bank branch 1	0.44	0.14	0.54
Bank branch 2	0.91	0.15	1.00
Bank branch 3	0.52	0.13	0.51
Bank branch 4	0.26	0.10	0.00
Bank branch 5	0.45	0.10	0.16
Min	0.26	0.10	0.00
Max	0.91	0.15	1.00

Table 10.12 Final ranking

Banks	Q_i	Ranking
Bank branch 1	0.536	4
Bank branch 2	1.000	5
Bank branch 3	0.505	3
Bank branch 4	0.000	1
Bank branch 5	0.165	2

10.7 Conclusions

In today's competitive environment, recognizing some factors that help company to overcome with their competitors are important issue. Many recent papers have shown that human resource is the most important competitive advantage in today's organizations. One of the major issues in HRM is employee empowerment, and for this reason some authors tried to find main factors that influence the empowerment.

This paper proposed a new model according to ranking bank branches in field of employee empowerment issues. This model is the combination of Fuzzy AHP and VIKOR methods and selects the best banks and their main criteria in field of employee empowerment based on evaluation of factors that have major impacts on quality of employee empowerment. Different from other studies in the literature, this study FAHP and VIKOR methods used together. FAHP used for determining the weights of the criteria and VIKOR method used for determining the ranking of the banks.

This study evaluated eight main factors in five bank branches of Agri bank. Other banks can use these methods in their branches before evaluating whole banks; it could help them to recognize that what exactly the main factors in each bank branch that influence its employee empowerment are.

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Chapter 11
Research on Innovation Capability of National High-tech Zones: Model Building and Empirical Analysis

Jiangfu Zhang and Xin Gu

Abstract The paper builds a theoretic innovative model of national high-tech zones according to the characteristics of regional innovation system. Based on the regional panel data of 56 national high-tech zones in 2011, the author analyses their innovation abilities through the way of principal component analysis. The results show that the innovation ability of the national high-tech zone is mainly embodied in the three principal component factors and the input of scientific and technical personnel and funds, technology innovation activities, innovation efficiency. Besides, the innovation ability of utility value, which are the three principal component factors of 56 national high-tech zones possess, is not consistent. In addition, the input of scientific and technical personnel and funds is closely related to innovation ability of high-tech zones. Lastly, the innovation ability of the national high-tech zones still has a “high in the East, medium in the Middle Part, low in the West” pattern.

Keywords National high-tech zones · Regional innovation system · Innovation ability · Principal component analysis

11.1 Introduction

Since 1991, China has successively established 56 national high tech Industrial Development Zone (calls it NHTZ for short). NHTZ has become Technology Industrial Park to gather resources for innovation and promote the development of high

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280, DOI: 10.1007/978-3-642-55182-6_11, © Springer-Verlag Berlin Heidelberg 2014

tech industry, which makes an important contribution in promoting local and national economic development. According to statistics: China's identified high-tech enterprises has soared from around 2,587 in 1991 to 51,764 in 2011, and employment growth from 12 to 859 million. Profits increased from 8 billion yuan to 6,261 billion yuan, the corporate tax increase from 39 billion yuan to 4,968 billion yuan, export growth from 1.8 to 2,476 billion. In the past 20 years, China's growth rate of the main economic indicators of NHTZ is more than 70 %, NHTZ plays an important role in promoting the regional innovation capacity. The research on innovation ability of NHTZ belongs to the RIS category, through summarizing the research of regional innovation capacity at home and abroad, it's mainly reflected in four aspects: First, research on the factors influencing regional innovation capability, OECD focuses on R&D investment contribution to the role of regional innovation capability. Based on this evidence, Zhu province believes that cannot ignore the role of non R&D investment, its effect is significant to the region innovation ability [11]; Second, construct the index system of regional innovation capability, to build up a set of suitable for comprehensive evaluation of regional innovation ability index, Liu established five indicators to comprehensive evaluate Regional Innovation Capability according to the situation of Chinese, including: knowledge creation capability, knowledge flow capability, enterprise innovation capability, innovation environment, innovation economic performance and some small index to evaluate Chinese provinces of regional innovation capability [7]. Third, the evaluation method of regional innovation ability, including quantitative methods such as AHP, DEA [5], and Malmquist index [10], and qualitative evaluation methods that focus on Innovation performance participatory, non-economic indicators about the body in the innovation process and innovation performance affect each other [8]. Fourth, the comparative study of regional innovation capability. Sun use the "Provinces" for regional unit, has evaluated regional innovation capacity in different provinces of China [9]. Foreign scholars Asheim and Coenen has make a comparative analysis of Norway's three regional industrial clusters [2]. Cooke comes to a conclusion that different regions have different innovation mode, through a comparative study on the America Massachusetts and Cambridge two regional high-tech biotechnology industry [4]. Based on the opinion of scholars on the basis of summarizing, the author raised three issues:

- First, as the high-tech industry gathering area, whether the NHTZ constitute the regional innovation system, namely, whether the NHTZ meets the basic conditions for regional innovation systems?
- Second, each region has its different regional innovation model, how to select the high-tech zones to reflect the index system innovation capability?
- Third, there's a number of regional innovation capability evaluation methods, how to select the appropriate evaluation methods to evaluate the NHTZ innovation capability?

These problems are the paper aims to solve.

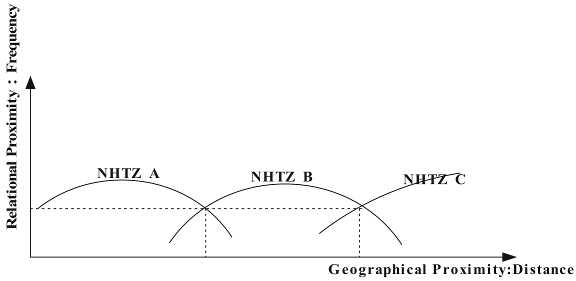

Fig. 11.1 Relational proximity and geographical proximity of NHTZ

11.2 NHTZ Innovation Capability Model

In the regional innovation system, the word "region" has two aspects meaning: First, the geographical boundaries of the region, such as the division of administrative regions; Second, the functional region, such as the formation of a target based on cooperation, trust and other relations [6]. Geographical boundaries pay attention to the knowledge transfer and spillover advantage of regional proximity. The functional region put forward the the proximity of relationship is conducive to the formation of innovation ability. But both can promote effective the formation of regional innovation capability, and the NHTZ reflect the organic combination of geographical and functional region (as shown in Fig. 11.1).

Innovation System can be divided into three levels: (1) National Innovation System (NIS), (2) Regional Innovation System, (3) Sectional Innovation System (SIS) [1]. NHTZ belongs to the regional innovation system level, is a place of high-tech industry cluster, the high-tech industry cluster is associated with each other (complementary and competing) in the high-tech in the field of enterprises and institutions gather in a certain region, to form an upper, middle and lower structurally-complete, and peripheral supporting industrial system and creative energy organic system. Within this space gathering system, innovation subject (enterprises, institutions, service organizations at NHTZ) through multilateral trading learning, communication activities, in order to agglomeration and the formation of innovation network interaction as a link, promote multilateral inter subjective knowledge dissemination and diffusion, interdisciplinary and industrial integration, the formation of innovation ability of NHTZ.

Therefore, the basic conditions of NHTZ with the regional innovation system is:

1. There are subjects with innovation ability, including the University and Research Institute, the core enterprise, government, intermediary service institutions and financial organization.
2. Based on the flow of innovative factors, the regional innovation subjects form all the relationships, such as cooperation, competition and trust relationship.
3. Supported regional innovation infrastructure, system and social environment, such as transportation, education and research infrastructure, policy system and innovative culture atmosphere.

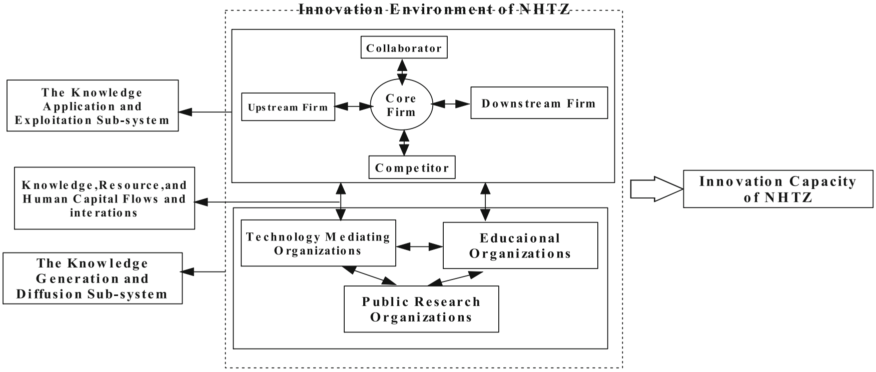

Fig. 11.2 An empirical analysis of the NHTZ innovation capability

And the innovation system of NHTZ can be divided into two subsystems, including knowledge application and development, knowledge production and diffusion [3]. The sub system of knowledge application and development is mainly composed of regional innovation of enterprises, in particular to vertical industry chain (the core enterprise, related upstream and downstream enterprises) and lateral chain (core business partners and competitors). Innovation capacity is forming at Enterprise-centric crisscrossing network; The subsystem of knowledge production and diffusion is mainly constituted by universities, research institutes and agencies. Knowledge is mainly produced in public organizations (such as research organizations, educational institutions), diffusion and spread through intermediaries, labor intermediaries and other supported innovation regional institutions. The two subsystems are not independent division, there is a flow of human capital, capital, and knowledge of innovative elements, with the support of regional innovation environment together constitute the NHTZs innovation system, each element interacts with the ability to influence the formation of innovative NHTZ. Therefore, in this article, the NHTZ is defined as: In order to improve the innovation capacity in the region, take the high-tech industry cluster in the region as the basis, and maximize the synergy of each subjective innovation, optimizing the configuration area resources (such as personnel, capital and knowledge, etc.), aimed at improving the innovation ability of NHTZ innovation systems through innovative activities, specifically as shown in Fig. 11.2.

11.3 Evaluation Index

Based on the innovation capability of high-tech zone model of the article, the connotation of the innovation capability of NTHZ is that, in order to promote the local and national economic growth, the NTHZ (such as Baotou Rare-Earth Hi-tech Zone, Zhangjiang Hi-tech Zone) is the basic unit of regional Innovation, the University,

Table 11.1 List of variables and summary statistics

First-grade index	Second-grade index	Unit	Abbreviation
Innovation Capacity index	Numbers of enterprises	Hundred	Ne
	Employee	Ten thousand	Ep
	Science and technology personnel ratio	Percentage	St
	Senior professional titles ratio	Percentage	Sp
	Junior college and above ratio	Percentage	Jc
	Per capita assets	RMB one hundred million /person	Ca
	Science and technology activity expenses within budget	RMB one hundred million	Sa
	Science and technology activity expenses outside spending	RMB one hundred million	Sc
	RD expenses within budget	RMB one hundred million	Rd
	Total industrial output value	RMB one hundred million	Ti
	Industrial added value	RMB one hundred million	Ia
	Per capita net income	RMB ten thousand/person	Cn
	Pay tax ratio	Percentage	Tr
	Export ratio	Percentage	Er
	Debt	RMB one hundred million	Db
	Technical income ratio	Percentage	Te
	Product sales ratio	Percentage	Ps
	Commodity sales ratio	Percentage	Cs
	Gross trading income	RMB one hundred million	Gt

scientific research institutions, intermediary service institutions, enterprises and government innovation subject integrated, and play a synergistic efficacy between innovation subject resources, optimize the allocation of resources within the region so that the knowledge, information can transform to new products, new technology and the capability of new services. So the evaluation of innovation capability of NTHZ should grasp three principles: First, cooperative principle, innovation is not only produced in a single organization or institution, but also includes the coordination of regional innovation between organizations; Secondly, efficiency Principle, innovation capability should reach resource optimization and form the target of Input and output efficiency. Thirdly, commercial principles, the mere technological knowledge does not constitute the innovation capability, innovation capability is the knowledge, technology and information into new products, new technology and new energy services.

According to NTHZs innovation systems, capabilities and principles, the paper pre-selected key indicators of innovation capability (see Table 11.1).

In order to ensure the reliability and validity of measurements, the paper adopts the Delphi method and the variation coefficient method to test the theoretical construct indicators of reliability and validity.

Firstly, use the Delphi method to test theory indicators reliability, the specific steps are as follows:

1. According to the index system of theoretical constructing, take the 7-point Likert scale developed questionnaire consulting table;
2. Selection of experts, from the 56 CMC of NHTZ, and enterprises, research institutes, universities and other institutions were randomly selected 180 experts as questionnaire investigation. they have been long engaged in the regional innovation ability of high-tech zone of the practice and theoretical research, has a wealth of knowledge and experience;
3. Fill in the questionnaire consulting tables through the mail, on-site investigation to experts.
4. Recovery of the questionnaire. The effective recovery of the questionnaire is 159, the recovery rate is 88.33 %.
5. Collation, analysis of the questionnaire. Suppose the index i in the x_i, the j expert selection score is B_{ij}, that the total score A in the index for x_j for 159 experts is: $A = B_{i1} + B_{i2} + \cdots + B_{i159} = \sum_{j=1}^{159} B_{ij}$.

The reliability A_i of index x_i is: $A_i = \sum_{j=1}^{159} B_{ij}/1113$.

If A_i approaches 1, index x_i has high reliability in the evaluation of NHTZ supported innovation-driven development, namely at the 7-point scale, most experts select the very important options; Conversely, when A_i close to 0, the index is not important, when $A_i \leq 0.4$, shows that at the 7-point scale, most experts select the unimportant options, the reliability of the index x_i is low, it can be deleted. And, use Coefficient of variation $(C.A)$ to delete the index that can't be distinguished the difference in index system to test validity, the formula is: $C.V_i = S_i/\overline{\Omega_i}$, where, Ω_i is the Observations of the index x_i. When the characteristic value $C.V_i$ is greater, that the discrete data of index x_i is high, the difference of index data is very obvious, can reflect the differences in the degree of innovation-driven development, and has high validity; Instead, when $C.V_i$ reaching to 0, the index x_i has low validity.

Finally, According to the Delphi method and the coefficient of variation, we selected the observed datas of 56 NHTZs in 2011 to calculate the characteristic value A_i and $C.V_i$ of each index, to test its reliability and validity, as specified in Table 11.2.

According to index of reliability and validity testing table, the paper select the number of enterprises (Ne), number of employees (Ep), scientific and technical activities staff ratio (St), the senior staff ratio (Sp), science and technology activities Intramural Expenditures (Sa), R&D Intramural Expenditure (Rd), industrial added value (Ia), per capita net income (Cn), pay tax ratio (Tr), exports ratio (Er), technology-income ratio (Te), total revenue (Gt) and other indicators to evaluate the innovation capability of NHTZ.

Table 11.2 List of variables and summary statistics

Index	A_i	$C.V_i$	Index	A_i	$C.V_i$
Ne	0.69	2.29	Ep	0.75	1.03
St	0.74	0.44	Sp	0.68	0.52
Jc	0.73	0.28	Ca	0.55	0.38
Sa	0.77	1.40	Sc	0.29	–
Rd	0.67	1.28	Ti	0.33	–
Ia	0.57	0.64	Cn	0.79	0.55
Tr	0.83	0.51	Er	0.44	1.25
Db	0.22	–	Te	0.76	1.26
Ps	0.62	0.16	Cs	0.26	–
Gt	0.88	1.26			

11.4 Data and Model

The paper selected evaluating indexs of statistical panel data in 2011 from 56 NHTZs to analyze, data mainly from the "China high-tech industry Yearbook in 2011", "China hi-tech industry development zone Yearbook In 2011", and "China Torch statistical Yearbook in 2011" and other categories of NHTZ statistical Yearbook. Using principal component model (PCA) to evaluate the innovation capability, which has two advantages: First, it can avoid subjectivity empowerment, Usually, empowerment weight is very subjective, which can affect the validity of evaluation results; Second, Remove the correlation of multivariable. The correlation of multiple variables will lead to repeated use of data, that the evaluation results is difficult to reflect the true situation of evaluation objects.

The research objects has a total of $n(56)$ samples, each sample select $p(12)$ variables to evaluate innovation capability, and constitute a $n \times p$ data matrix:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1p} \\ x_{21} & x_{22} & \cdots & x_{2p} \\ \vdots & \vdots & \vdots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{np} \end{bmatrix}, \quad (n = 56, \ p = 12)\,. \tag{11.1}$$

Because the variable p is more, this paper used synthesis variable Z instead of the original variable p to reflect the information, make $x_1, x_2, \cdots, x_{12}$ for the original variables, $z_1, z_2, \cdots, z_m$ as new variables, change the original variable X in Eq. (11.1) into new variable Z:

$$Z = \begin{cases} z_1 = l_{11}x_1 + l_{12}x_2 + \cdots + l_{1p}x_p \\ z_2 = l_{21}x_1 + l_{22}x_2 + \cdots + l_{2p}x_p \\ \quad \vdots \\ z_m = l_{m1}x_1 + l_{m2}x_2 + \cdots + l_{mp}x_p \end{cases} \quad (m \le 12, \ p = 12)\,. \tag{11.2}$$

In the Eq. (11.2), the new variables $z_1, z_2, \cdots, z_m$, are known as the components of first, second or m of the original variables $x_1, x_2, \cdots, x_p$.

First, r_{ij} $(i, j = 1, 2, \cdots, 12)$ is the correlation coefficient of original variables x_i and x_j, according to Eq. (11.1), calculate the correlation coefficient matrix of the p-original variables.

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1p} \\ r_{21} & r_{22} & \cdots & r_{2p} \\ \vdots & \vdots & \ddots & \vdots \\ r_{p1} & r_{p2} & \cdots & r_{pp} \end{bmatrix} (p = 12)\,. \tag{11.3}$$

Secondly, according to Eqs. (11.2) and (11.3), the solution of the characteristic equation to calculate the eigen values, the principal component contribution rate Φ_i and cumulative contribution rate Φ:

$$\Phi_i = \frac{\lambda_i}{\sum_{k=1}^{12} \lambda_k} \ \ (i = 1, 2, \cdots, 12). \tag{11.4}$$

According to Eq. (11.4), it can calculate the cumulative contribution rate of its principal components before i:

$$\Phi = \Phi_1 + \Phi_2 + \cdots + \Phi_i = \frac{\sum_{k=1}^{i} \lambda_k}{\sum_{k=1}^{12} \lambda_k} \ \ (i = 1, 2, \cdots, 12). \tag{11.5}$$

Finally, take the contribution rate of each principal component as weighting factor, change each index value into the standard value, and calculate the value of the evaluation and comprehensive evaluation value of principal component:

$$F_i = e_{i1}zx_1 + e_{i2}zx_2 + \cdots + e_{ij}zx_j (i, j = 1, 2, \cdots, 12), \tag{11.6}$$

$$F = \frac{\lambda_1}{\sum_{i=1}^{12} \lambda_i} * F_1 + \frac{\lambda_2}{\sum_{i=1}^{12} \lambda_i} * F_2 + \cdots + \frac{\lambda_i}{\sum_{i=1}^{12} \lambda_i} * F_i. \tag{11.7}$$

In Eq. (11.6), e_{ij} is the principal component load, zx_j is the standardized values for the variables x_j, and the innovation capability of NHTZ can be evaluated by using Eqs. (11.6) and (11.7).

11.5 The Empirical Results Analysis

The PCA model is complex in calculation, this paper use SPSS17.0 software to evaluate the innovation capability of the 56-NHTZ from the following three aspects: Descriptive statistics of innovation variables, influencing factors of regional innovation capability, and the innovation capability ranking.

Table 11.3 List of variables and summary statistics

	Ne	Ep	St	Sp	Sa	Rd	Ia	Cn	Tr	Er	Te	Gt
Ne	1	0.94	0.27	0.10	0.88	0.87	0.48	0.16	−0.14	−0.08	0.35	0.93
Ep		1	0.35	0.03	0.95	0.94	0.69	0.19	−0.22	0.02	0.36	0.97
St			1	0.33	0.48	0.49	0.52	0.28	−0.05	−0.21	0.29	0.40
Sp				1	0.11	0.12	0.19	0.15	0.07	−0.24	0.21	0.09
Sa					1	0.98	0.71	0.31	−0.18	−0.06	0.33	0.96
Rd						1	0.69	0.26	−0.18	−0.05	0.41	0.94
Ia							1	0.44	−0.22	0.00	0.25	0.69
Cn								1	−0.35	−0.30	0.11	0.35
Tr									1	−0.16	−0.14	−0.20
Er										1	−0.20	−0.04
Te											1	0.32
Gt												1

11.5.1 Descriptive Statistics of Innovation Variables

The descriptive statistics of NHTZ-12 indicators is be normalized, and into the correlation coefficient matrix, get the correlation coefficient matrix between indexs (see Table 11.3). The Table 11.3 shows, the number of variable enterprises (Ne), and the the number of employees (Ep), science and technology activities Intramural Expenditures (Sa), R&D Intramural Expenditure (Rd), and total revenue (Gt) was significant correlation. The number of employees (Ep), technology activities Intramural Expenditures (Sa), R&D Intramural Expenditure (Rd), total revenue (Gt) were significant correlation. The variables of science and technology activities Intramural Expenditures (Sa), R&D Intramural Expenditure (Rd) and total revenue (Gt) were significant correlation. R&D Intramural Expenditure (Rd) and total revenue (Gt) were significantly correlated.

11.5.2 Principal Component Factor Analysis of Innovation Capability

Equations (11.4) and (11.5) calculate the principal components corresponding contribution rate and cumulative contribution rate (see Table 11.4). According to the two principles of PCA model, (1) varimax rotation method, (2) eigen values was greater than 1, and the extraction of the principal component. From Table 11.4, the Variance contribution rate of the first principal component was 48.78 %, the second variance contribution rate was 18.47 %, the third was 15.41 %, the cumulative variance contribution rate was 82.66 %, the three main components that can be used to explain the original 12 evaluation indexes about 80 % of the variance, so we just calculate the three principal component z_1, z_2, z_3 to evaluate the innovation capability of NHTZ.

Table 11.4 List of variables and summary statistics

Principal component	λ_i	$\Phi_i\,(\%)$	$\Phi_i\,(\%)$
Z_1	5.85	48.78	48.78
Z_2	1.62	18.47	67.25
Z_3	1.25	15.41	82.66
Z_4	0.88	5.32	87.98
Z_5	0.87	4.28	92.26
Z_6	0.64	3.32	95.58
Z_7	0.44	1.71	97.29
Z_8	0.30	1.53	98.82
Z_9	0.10	0.83	99.65
Z_{10}	0.02	0.17	99.83
Z_{11}	0.01	0.12	99.94
Z_{12}	0.01	0.06	100.00

Table 11.5 List of variables and summary statistics

	z_1	z_2	z_3
x_1	0.88	−0.21	0.22
x_2	0.95	−0.26	0.10
x_3	0.14	0.88	0.01
x_4	0.19	0.66	0.18
x_5	0.97	−0.11	0.07
x_6	0.96	−0.11	0.11
x_7	−0.21	0.10	0.77
x_8	0.39	0.42	−0.64
x_9	−0.26	0.14	0.80
x_{10}	−0.11	0.29	−0.16
x_{11}	0.45	−0.71	0.13
x_{12}	0.05	−0.16	0.97

About the extracted three principal components for the corresponding eigenvalues, by using the Eq. (11.6) to calculate the load of variables $x_1, x_2, \cdots, x_{12}$ on the principal component z_1, z_2, z_3 (Table 11.5). The first principal component z_1 was significantly stronger positive correlation with indicators Ne, Ep, Sa, Rd, which is a comprehensive reflection of the staff and investment funding of NHTZ. The second Principal component z_2 has a stronger positive correlation with indicators St, Sp, but has significantly stronger negative correlation with Te. St, Sp, Te reflects technology innovation activities of the NHTZ, The third principal component index z_3 has a strong positive correlation with Ia, Tr, Gt,but a strong negative correlation with the index Cn, Ia, Cn, Tr, Gt reflects the output efficiency of the NHTZ, and the principal component z_3 represents innovative output efficiency of NHTZ.

Table 11.6 List of variables and summary statistics

NHTZ	$\hat{F}_1$	Ranking	$\hat{F}_2$	Ranking	$\hat{F}_3$	Ranking	$\hat{F}$	Ranking
Beijing	100	1	10	55	74	4	100	1
Shanghai	46	2	50	20	21	55	43	2
Wuhan	35	3	51	17	55	18	35	3
Xian	34	5	62	6	55	19	34	4
Guangzhou	34	4	25	52	47	30	30	5
Shenzhen	31	7	56	11	42	34	30	6
Chengdu	32	6	46	29	42	36	30	7
Hangzhou	28	8	10	54	56	17	24	8
Tianjin	27	9	29	49	37	49	23	9
Zhengzhou	22	14	71	4	47	29	22	10
Nanjing	22	12	62	7	33	52	21	11
Changchun	24	10	73	2	0	56	20	12
Dalian	23	11	37	42	49	26	20	13
Shijiazhuang	18	18	72	3	50	25	18	14
Wuxi	22	13	39	36	28	53	18	15
Zhongshan	15	26	100	1	48	28	17	16
Changsha	19	15	52	15	41	38	17	17
Shenyang	19	17	38	39	49	27	16	18
Jinan	19	16	29	50	54	20	16	19
Zibo	16	21	48	25	69	7	16	20
Hefei	15	25	52	16	70	6	16	21
Weifang	17	20	70	5	25	54	15	22
Taiyuan	14	29	50	18	74	3	14	23
Qingdao	16	23	61	8	40	40	14	24
Suzhou	17	19	34	44	39	43	13	25
Baotou	13	32	53	13	53	22	12	26
Haerbing	13	34	50	21	60	11	12	27
Foshan	16	22	39	38	37	48	12	28
Nanchang	9	46	57	10	90	2	12	29
Anshan	14	27	46	28	45	32	12	30
Xiangfan	14	31	39	37	57	15	12	31
Jilin	12	38	44	30	71	5	11	32
Changzhou	15	24	35	43	38	46	11	33
Baoji	12	39	50	19	56	16	11	34
Daqing	12	36	43	34	58	14	11	35
Luoyang	13	35	43	33	51	24	10	36
BaoDing	12	37	57	9	34	51	10	37
Nanning	14	30	20	53	52	23	9	38
Zhuhai	14	28	31	45	39	45	9	39
Zhuzhou	10	44	47	27	58	13	9	40
Weihai	11	41	53	14	39	42	9	41
Kunming	11	42	54	12	39	44	8	42
Xiangtan	9	47	49	23	63	9	8	43

(continued)

Table 11.6 (continued)

NHTZ	$\hat{F}_1$	Ranking	$\hat{F}_2$	Ranking	$\hat{F}_3$	Ranking	$\hat{F}$	Ranking
Xiamen	10	43	48	26	41	39	8	44
Fuzhou	10	45	50	22	44	33	7	45
Ningbo	11	40	31	46	36	50	7	46
Chongqing	13	33	0	56	45	31	7	47
Lanzhou	8	49	43	32	62	10	6	48
Mianyang	8	48	30	48	54	21	4	49
Guilin	6	52	37	41	60	12	4	50
Taizhou	7	50	42	35	42	37	4	51
Wulumuqi	6	51	38	40	39	41	2	52
Yangling	0	56	49	24	100	1	2	53
Guiyang	5	54	25	51	67	8	2	54
Huizhou	6	53	44	31	37	47	2	55
Hainan	5	55	30	47	42	35	0	56

11.5.3 Innovation Capability Evaluation

Using Eqs. (11.6) and (11.7) to calculate principal component z_1, z_2, z_3 corresponding F_1, F_2, F_3 evaluation value and comprehensive evaluation value F. For comparison analysis, we take the evaluation value F_1, F_2, F_3, F to be normalized, the formula is:

$$\hat{F} = \frac{x_i - x_{\min}}{x_{\max} - x_{\min}}. \tag{11.8}$$

$\hat{F}$ is the evaluation value of F_1, F_2, F_3, F after ormalization, Its value in the range [0, 100], $x_{\min}$ and $x_{\max}$ is the minimum and maximum of F_1, F_2, F_3 evaluation value, respectively.Using formula (11.8) for F_1, F_2, F_3, F original evaluation, get the innovation capability evaluation value table of NHTZ (see Table 11.6).

11.6 Conclusions and Recommendations

This paper theoretically builds the innovation system mode of NHTZ, and then further through an empirical analysis of the influence principal component factor of innovation capacity of NHTZ, evaluation of each principal component factor of the innovation capability of the utility value and comprehensive innovation capability, thus providing a theoretical basis for the scientific judgment of the policy effect. Results and conclusion is embodied in the following aspects.

First, the innovation capacity of NHTZ is mainly reflected in three aspects, that the scientific and technical personnel and founding, technology innovation and innovation output efficiency.

Second, in the three principal component of the scientific and technical personnel and funding, technological innovation and innovation output efficiency, scientific and technical personnel and funding has close relationship with the supported development of innovation-driven, which directly affects the regional innovation capability of ranking. Therefore, it should grasp the key aspects to increase the scientific and technical personnel and funding when evaluate the innovation capability.

Third, the three principal component of the evaluation values are not the same, and does not appear the same height with low convergence phenomenon. NHTZ like Beijing, Shanghai, Wuhan, Xi'an, Guangzhou has a higher points in the evaluation of personnel investment, NHTZ like Zhongshan, Changchun, Shijiazhuang, Zhengzhou and Weifang dominate in the evaluation of the technological innovation, Yangling, Nanchang, Taiyuan, Beijing and Jilin dominate in the evaluation of innovation output efficiency.Therefore, 56-NHTZ has its own characteristics, there is no uniform optimal development model, policy makers should recognize the advantages of the development of regional characteristics, local conditions suitable for various NHTZ to explore innovation-driven model of development.

Fourth, the pattern of NHTZ of regional innovation capability presents the characteristics of "Eastern high, Central medium, low in the Western." The innovation capability in eastern coastal areas is strong. Apart from the central region of Zhengzhou, innovation capability of other high-tech zones are all of sorts. The western Hi-tech Zones are weak except for Chengdu. Therefore, it's need for the eastern to maintain and play a leading role, and increase the technology personnel, funding and policy support to the Central and Western.

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Chapter 12
Who Knows What and Who is Reliable: Transactive Memory System in Multiactivity Task Environment

Chen Zhao and Zhonghua Gao

Abstract In this research, we examine that how TMS works in a multiactivity task environment. We propose that the development of TMS, an ongoing feed forward and feedback process to improve the group performance, depends on the establishment and confirmation of credibility in group members' transactive memory. Using the computer simulation, we determine the effects of multiactivity task attributes on group task performance through establishing a TMS model. The virtual experimental results indicate that interdependence, dynamics, implicitness, and the interaction of these three attributes are negatively related to group task performance in different degrees.

Keywords Transactive memory system · Multiactivity task · Group performance · Agent-based simulation · Group learning

12.1 Introduction

Researches on transactive memory systems provide lots of compelling evidences to the fact that group cognition, which can be reflected by the transactive memory system (TMS), influences collective performance [18]. As been widely revealed, TMS is a group-level collective system for encoding, storing, and retrieving information that is distributed across group members [25]. Usually, in groups with a well-developed TMS, members specialize in different knowledge and have a common cognition about the knowledge possessed by each member. Thus, TMS is often

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_12,

considered as “a shared understanding of who knows what”. Based on members' clear understanding of the specialized expertise that each member possesses, group performance might be improved through TMS because it can provide quick and coordinated accesses to group members to get a greater amount of high-quality and task-relevant knowledge [14].

Most of the published TMS studies were conducted in laboratory using newly formed ad-hoc groups for the special purpose of studying TMS [15]. These groups were generally asked to complete a single task (e.g. assembling radios) and were disbanded when the task was complete. These studies revealed that the groups trained collectively performed better than other groups trained individually and that the relationship between training and performance was mediated by the existence of a TMS [3]. In addition, based on the measurement scales developed by Lewis [13] and Austin [3], some field studies were published recently [6, 29]. However, it is regrettable that these field studies paid more attention to the antecedents and consequences of TMS and were rarely concerned with the dynamic task demands from organizational workgroups [2, 17]. On the whole, most of the previous studies were conducted in a simple and static task environment.

In fact, workgroups in organizations might encounter a large variety of group tasks. Many organizational workgroups engage in tasks characterized by dynamic complexity, and are performing activities that cannot fall clearly into the same type. Meanwhile, the tasks which involve a set of coordinated activities are time-bound, with specific start and completion dates, and proceed in a series of phases that can form a complete project life cycle together. Thus, the main purpose of this paper is to extend the TMS research into the multiactivity task environment in consideration of the attributes of interdependence, dynamics, and implicitness.

We begin our discussion by presenting a general framework which reveals the relationships among multiactivity task attributes, TMS, and group task performance. This framework provides the conceptual foundations for this study and describes the elements and the logic of the simulation model. We then outline the model specification and parameters before reporting the results and analysis of the model runs. Finally, we conclude several suggestions for future research in discussion section.

12.2 A Theoretical Framework

12.2.1 TMS in Multiactivity Task Environment

We advocate that the usefulness of a TMS depends not only on a shared understanding of who knows what but also on the degree to which group members know who is more reliable to do what. Thus, we deem that TMS development depends on the establishment and confirmation of the credibility. In the following sections, we analyze how the characteristics of TMS relate to the credibility and affect group task performance in multitask activities (See Fig. 12.1).

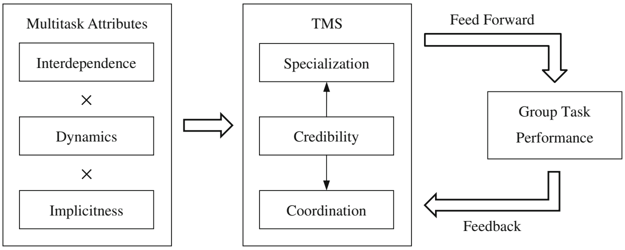

Fig. 12.1 The theoretical model of the relationships among multiactivity tasks attributes, transactive memory system, and group task performance

Credibility Updating. Brandon and Hollingshead [5] argue that the development of TMS involves a cycle of construction and evaluation of the hypotheses regarding other team members' knowledge, abilities, and credibility. On the one hand, it takes time and effort to discern who is good at what. On the other hand, the accurate expertise perceptions at one period may be obsolete at another period because of the dynamic task environment. Thus, group members will keep modifying their perceptions of others' expertise over time from crude perceptions based on the surface characteristics to more accurate conceptions of group members' expertise. As group members begin to perform tasks and start receiving performance feedback, they accurately gain a better understanding of each other's expertise and keep adjusting their existing credibility.

Knowledge Refining. Compared with the perception adjustment toward others during the transactive memory updating process, knowledge refining is more concerned with self-reflection. Social learning theory suggests that feedback achieved through learning by doing and vicarious learning acts as a powerful reinforcing mechanism of behaviors. Performance feedback, especially the negative performance feedback, may evoke group members' reassessment on the accuracy of their own expertise. Therefore, the credibility is an important moderator between diagnostic performance feedback and expertise modification.

Expertise Coordination. Because of the fact that organizational workgroups sometimes are partially specialized and group members' expertise is to some extent overlapped, it is common that there are more than one member-expertise associations ready to be accessed when a member who is responsible for some subtask needs external memory aids. One reason is that many group members bring their versatility to the group at its inception. Another is that group members can learn from others during the previous task processing.

The overlapped knowledge in a group poses a challenge to coordination. To ensure the completion of a subtask, the responsible member will choose the most trusted expert who possesses that special knowledge. In other words, a group matches a person with the special expertise according to the credible knowledge of the responsible member's transactive memory. The coordination based on trust is conducive to accomplish the group task. On the one hand, the providers expect that any knowledge they share will be accepted by the receivers without questions about their competence. On the other hand, the receivers know that the providers will provide them with the accurate, reliable, and complete knowledge. Trust should therefore enhance team members' uses of each other's expertise to store and retrieve knowledge and thus strengthen the influence of the location dimension of transactive memory on performance [22].

In summary, we believe that the feed forward and feedback between TMS and group performance is mediated by the establishment and confirmation of credibility in group members' transactive memory. Group members choose the most reliable partners to work together so as to achieve good performance. Based on performance feedback, group members update their existing credibility and refine the expertise knowledge for the coming subtasks.

12.2.2 Multiactivity Task Attributes

Because the group task determines the specialization demands and coordination processes, recently published TMS studies repeatedly stressed the task attributes in TMS research [4, 5, 9, 14, 28]. Compared with the simple and static tasks that are engaged by the groups in TMS laboratory studies, multiactivity tasks are more often engaged by organizational workgroups in actual situations. The dynamic complexity is one of the major characteristics for all multitask activities, and thus the group processes and the demands for the knowledge and skill change throughout the life cycle of the group's work [14, 21]. In order to well perform the multitask activities, a group with TMS will develop task representations that include how the task can be broken down into component parts and who should perform a subtask to achieve the overall goal [13]. We recognize that each subtask has three typical features: interdependence, dynamics, and implicitness.

Interdependence. Interdependence refers to the extent to which group members need knowledge, skills, and support from other group members. The knowledge must be acquired from other group members through the retrieval and coordination processes to effectively complete the subtask. Previous studies mostly investigated task interdependence from the cognition point of view. For instance, Zhang and Hempel [28] manifested that task interdependence perceived by team members is positively related to the team's TMS. Yuan and Fulk [27] demonstrated that task interdependence is positively related to individual expertise exchange. In this research, we focus on the interdependence that arises from different kinds of knowledge in a specific subtask, particularly on how variations in degree of knowledge from different expertise interdependence influence TMS and subtask performance.

In a simple and static task environment, the interdependence is a fundamental driving force. Group members are more likely to develop a TMS when group tasks are interdependent than when tasks are independent. But in a complex and dynamic task environment, group performance will dramatically decrease as tasks become more interdependent. When interdependence is in a low level, task representation is so clear that group members can easily recognize how many kinds of expertise are needed and find the most reliable partners to accomplish subtasks. Meanwhile, group members can distinguish that which expertise leads to the negative performance. Based on this, both TMS updating and knowledge refining proceed smoothly. In this way, more accurate TMS and expertise can facilitate the improvement of group performance. However, when interdependence is in a high level, group members must have an access to a large body of knowledge and combine each other's distributed expertise to carry out the tasks. Any inaccurate expertise can cause groups' failure to update the TMS and refine their knowledge. Therefore, as interdependence increases, group members will try harder and harder to understand each other's skills and coordinate their knowledge and expertise so that they are able to complete the tasks.

Hypothesis 1 Interdependence of a multiactivity task is negatively related to task performance.

Dynamics. Dynamics refers to the changing frequency of task demands. A dynamic and shifting environment creates commensurate group task demands that members have to resolve through a coordinated process that combines their cognitive, affective, and behavioral resources. However, the environment change is hard to predict, which means knowledge valid at one time can easily become counterproductive at another time without any symptoms. Besides, the environment change is not obvious, which means that it can be discovered only after making some mistakes. Essentially, group adaptation to the changing demands is mainly a process of collaboration and interaction among individuals, which is the base for learning from the mistake. If dynamics is in a low level, based on TMS, group members can reflect on their performance and its consequences, discover the cause and effect relationships, and identify the weaknesses and strengths in their own efforts. But if dynamics is in a high level, the obsolete knowledge retrieved from TMS cannot be used to solve the unexpected problems effectively. Besides, the limited cognitive resources are consumed during TMS updating and knowledge refining processes. Therefore, the more the group task demands dynamic, the worse the task performance achieved through TMS.

Hypothesis 2 Dynamics of a multiactivity task is negatively related to task performance.

Implicitness. Implicitness refers to the implicit part of expertise knowledge to accomplish group tasks. As pointed by previous studies, tacit knowledge is the knowledge that is difficult to be transferred to another person by the means of writing it down or verbalizing it. By anticipating what others in the group are likely to do, members can adapt their own behavior to facilitate the group's task completion without explicit discussion of who should do what [24]. The existence of tacit knowledge in multi-activity tasks is due to two reasons: first, the dynamics decreases the chance to code implicit knowledge into explicit knowledge because of group members' lack of cognitive resources; second, since each individual concentrates on his or her own expertise area, which increases the obstacles to transfer knowledge; third, the implicit coordination characteristic of TMS prevents changing the implicit knowledge into explicit knowledge.

Although the evidence from Lewis et al. [15] suggests that TMS can facilitate the transformation of prior knowledge to different tasks, they do not distinguish which kind of knowledge is learned and transferred. We advocate that the knowledge and experience, especially the explicit part, gained from a special area expert in one task can be stored in group member's memory and transferred to accomplish other tasks. If the percentage of tacit knowledge is low, group members are more likely to gain additional knowledge from an unfamiliar expertise area during the coordination of previous tasks. The result is that group members can partially reduce the dependence on the expert in that area when they meet a task that needs this part of knowledge next time. As more tasks can be finished by groups during the limited time, therefore group performance increases. When the percentage of tacit knowledge is high, group members are less likely to acquire new expertise knowledge. Thus, high implicitness is not conducive to the improvement of group performance.

Hypothesis 3 Implicitness of a multiactivity task is negatively related to task performance.

In addition to the main effects proposed in Hypotheses 1–3, we propose that interdependence, dynamics, and implicitness may interact with each other to influence the group task performance. It means that group will achieve the lowest performance if the engaged task has all three attributes at the same time.

Hypothesis 4 The interaction of interdependence, dynamics, and implicitness is negatively related to task performance.

12.3 The Simulation Model

12.3.1 Simulation Setting

Group Size. There are m individuals in a group. Because TMS effectiveness is contingent upon group size, the group size in our simulation model is determined by real organizational workgroup size. Devine and Clayton [7] report that the average size of new product development teams in the United States is 11 members. The Saratoga Institute's 2001 benchmarking study found that the average span of control of supervisors in U.S. companies ranged from four employees per manager (for information services) to 16 employees for healthcare organizations. Thus, we fix group size to 10 individuals during the simulation ($m = 10$).

Knowledge Representation. We use the framework of reality and beliefs to simulate TMS evolution. Reality represents the correct knowledge to accomplish multiactivity tasks. It is modeled as an n-dimensional vector with each element randomly assigned a value of 1 or -1 with equal probability. Each element of reality represents a piece of knowledge. The greater is n, the greater is the complexity of the group task.

The reality is equally divided into s areas of expertise. Adapted from Miller et al. [19] paper, each area of expertise contains explicit dimensions and tacit dimensions, and the portion of tacit dimensions in every area of expertise is represented by p. In our model, reality is fixed to contain 100 pieces of knowledge ($n = 100$), which corresponds to 10 areas of expertise respectively ($s = 10$). That means each area of expertise consists of 10 pieces of knowledge, and the number of tacit pieces of knowledge equals to 10 times p. Thus, p is an indicator for the implicitness attribute of multiactivity task.

Because organizational workgroups usually consist of members who join with knowledge and experience in particular areas, group members are randomly assigned one or two areas of expertise at the beginning of our simulation. The number of areas of expertise depends on the extent of group expertise diversity. Expertise diversity refers to differences in the knowledge and skill domains in which members of a group are specialized as a result of their work experience and education. In our model, expertise diversity can range from 1 when each individual possesses unique expertise to 2 when the group can be divided into two subgroups with equivalent function. We fix expertise diversity to 1.5 in simulation. Thus, the total number of areas of expertise in a group is 15, which is calculated by the product of expertise types and expertise diversity ($10 \times 1.5 = 15$). Then the 15 areas of expertise are randomly assigned to 10 individuals, and we make sure every individual corresponds to at least one area of expertise.

Each individual holds beliefs about the corresponding elements of reality at each period. Each dimension of beliefs has a value of 1, 0, or -1. A value of 0 reflects the absence of knowledge about a particular dimension of reality, whereas 1 and -1 indicate commitments to particular knowledge. At the beginning of the simulation, all the expertise dimensions of agent beliefs are consistent with reality, and the other dimensions are equal to 0.

Task Setting. In the model, we assume a group task in each period and that can be broken down to a set of subtasks. We adapt the classic *NK* model to generate subtasks. The *NK* model is named for the two parameters that are used to randomly generate problem spaces. It was originally developed by evolutionary biologist Kauffman to model epistasis, the genetic analog to synergies among human activities. Levinthal [12] firstly introduce *NK* model to organizational research. From then on, it has been widely used in the studies of organization management. In our model, n is interpreted as the number of potential pieces of knowledge needed to accomplish each subtask, and k is the typical amount of synergies among pieces of knowledge. In other words, the performance of any given subtask depends on the presence of k pieces of knowledge belonging to different areas of expertise respectively. The subtask can be accomplished only when all the k pieces of knowledge correctly reflect the corresponding dimensions of reality. Thus, k is used as a proxy for the interdependence attribute of multiactivity task.

Dynamics. Dynamics is episodic in our model. We perturb r proportion of dimensions in every expertise of reality (from 1 to -1, or from -1 to 1) at every d period. We fix r to 0.1 in our model. Thus, d is used as the only indicator to reflect the dynamics attribute of multiactivity task.

12.3.2 Interaction Process

Expertise Coordination. For each period, the group encounters n subtasks. The group coordinates these subtasks according to their performance, from most to least value. We assume that each subtask corresponds to a key expertise. Any subtask is assigned to a responsible agent who has the key expertise. Because organizational work groups engage a lot of activities that are time-bound, if the agent who possesses the key expertise cannot be found, group immediately gives up this subtask and starts to coordinate the next.

We assume all the agents can accurately and uniformly break subtasks down to different pieces of knowledge, which is a kind of shared knowledge in our model. To perform subtasks, agents may not possess all the necessary knowledge, so they need to search for the persons who have these pieces of knowledge in the group according to their transactive memory. We assume that even if agents have the required knowledge through previous individual learning, they can still choose to improve their skills or gain more knowledge by seeking help from experts of relevant areas. Only when TMS does not exist or they cannot find a suitable expert in TMS, do agents then estimate whether they themselves have the required knowledge. If responsible agents possess the required knowledge, they take this part of the subtask by themselves; otherwise they randomly choose an agent from available agents so as to know more people's expertise. If TMS exists and they can get more than one suitable expert, agents will choose the most reliable expert according to credibility. In this way, group members are assigned to subtasks based on their transactive memory of who knows what and who is more reliable to do what. Because we simulate the tasks involved complex knowledge and skills, group members need to indeed participate and not only just provide some simple information. Hence, we assume each individual can only work for one subtask in a period of time.

Credibility Updating. Credibility is gained by accumulation in the simulation model. We use an index to represent credibility. At the beginning, all the credibility in TMS is set to 0. If a subtask is successfully finished, all the individuals who participated are assigned plus 1 for each other's expertise in their transactive memory. If a subtask is failed, the value of credibility remains unchanged.

Existing Knowledge Refining. Individuals only refine knowledge when they get negative feedback. In the model, refining means inversing the value of knowledge dimension (from 1 to -1, or from -1 to 1). The likelihood of individuals refining their knowledge depends on knowledge refining probability. For any individual, we measure the probability for refining the knowledge dimension as follows:

$$\text{knowledge refining probability} = \frac{1}{a}\prod_{i=1}^{I}\frac{c_i}{Mc}, \tag{12.1}$$

where c_i takes on each element in the set of credibility index, respectively corresponding to which expertise of whom is used to perform the subtask. Mc represents the maximum credibility value in the individual's transactive memory in that period of time. Besides, a serves as a tunable parameter which changes according to the number of element in the set.

New Knowledge Learning. Individuals only learn from partners' expertise when get the positive performance feedback. Because of the nature of multiactivity task, we assume individuals can only learn explicit dimensions of expertise with probability e, and tacit dimensions cannot be learned in the simulation. In the model, e is fixed to 0.5.

12.3.3 Outcomes Measures

The groups go through 200 task periods. The second 100 task periods have exactly the same setting as the first 100 task periods, except that agents start to refine their knowledge based on the credibility developed during the first 100 task periods. At the end of each task period, performance is recorded by adding all the successful subtasks' performance value. All of performance collected at the end of each task period is averaged based upon 1,000 runs of the simulation model. Group task performance is the average of the 200 performance values.

12.4 Simulation Results

We constructed our simulation models using MATLAB 7.8. We use the model to run a series of simulations that examine the impact of multiactivity task attributes on group task performance through TMS. First, two interdependence conditions are simulated: low and high. Under low interdependence, each subtask consists of two kinds of knowledge respectively belonged to two different types of expertise ($k = 2$). Under high interdependence, each subtask consists of three kinds of knowledge ($k = 3$), which makes the coordination become more complex. Second, two dynamics conditions are simulated: low and high. Under low dynamic condition, the interval of reality change is 20 periods ($d = 20$). That means some dimensions of expertise in reality change at every 20 period. Under high dynamic condition, the interval of reality change is 10 periods ($d = 10$). Task dynamics increase as the decreasing of interval period number. Last, we design two implicitness conditions. Under low implicitness condition, the proportion of tacit dimension in every expertise is 0.2 ($p = 0.2$). Whereas, under low implicitness condition, the proportion of tacit dimension in every expertise is 0.8 ($p = 0.8$). Under such condition, it is hard to transfer knowledge from one person to another. Therefore, each of these three predictor variables was manipulated into a high and a low condition resulting in a $2 \times 2 \times 2$ complete factorial experimental design. We conducted all hypotheses tests using analysis of variance (ANOVA).

A three-way ANOVA (see Table 12.1) reveals a significant main effect for interdependence, $F(1{,}792) = 132{,}074.94$; $p < 0.001$, a significant main effect

Table 12.1 ANOVA summary

Source	df	SS	MS	F
Interdependence	1	554.15	554.15	132074.94***
Dynamics	1	1.16	1.16	277.43***
Implicitness	1	325.44	325.44	77564.02***
Interdependence × dynamics	1	0.04	0.04	9.45***
Interdependence × implicitness	1	3.99	3.99	951.63***
Dynamics × implicitness	1	0.63	0.63	150.79***
Interdependence × dynamics × implicitness	1	0.02	0.02	5.81***
Error	792	3.32	0.00	
Total	799	888.77		

Note $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

for dynamics, $F(1{,}792) = 277.43$; $p < 0.001$, and a significant main effect for implicitness, $F(1{,}792) = 77564.02$; $p < 0.001$. These results provide support for Hypothesis 1–3. Also, Table 12.1 reveals a significant interaction effect between interdependence and dynamics, $F(1{,}792) = 9.45$; $p < 0.01$, a significant interaction effect between interdependence and implicitness, $F(1, 792) = 951.63$; $p < 0.001$, and a significant interaction effect between dynamics and implicitness, $F(1{,}792) = 150.79$; $p < 0.05$. Last, as predicted in Hypothesis 4, the analysis revealed a significant three-way interaction between interdependence, dynamics, and implicitness, $F(1{,}792) = 5.81$; $p < 0.05$.

To more easily see the form of the interaction, we use two graphs to present conditions under which the multiactivity task attributes have effects on group task performance. As shown in Fig. 12.2, all three attributes, interdependence dynamics, and implicitness, have detrimental influence on group task performance in different degrees. The group undertaken low interdependence, low dynamics, and low implicitness tasks obtain the highest performance (4.80). In contrast, groups suffer the most in a high interdependence, high dynamics, and high implicitness task environment (1.77).

12.5 Discussion

This paper highlights the credibility of a TMS. Although there is a clear understanding in the literatures of psychology and management that TMS can influence collective performance by sharing cognitive labor, we advocate that the credibility accumulated from previous performance feedback is the core of a TMS in a multiactivity task environment. Based on this function mechanism, we develop an agent-based simulation model to examine the influence of multiactivity task attributes on group task performance through the TMS. The virtual experimental results show that interdependence, dynamics, implicitness, and the interaction of these three attributes are all negatively related to group task performance.

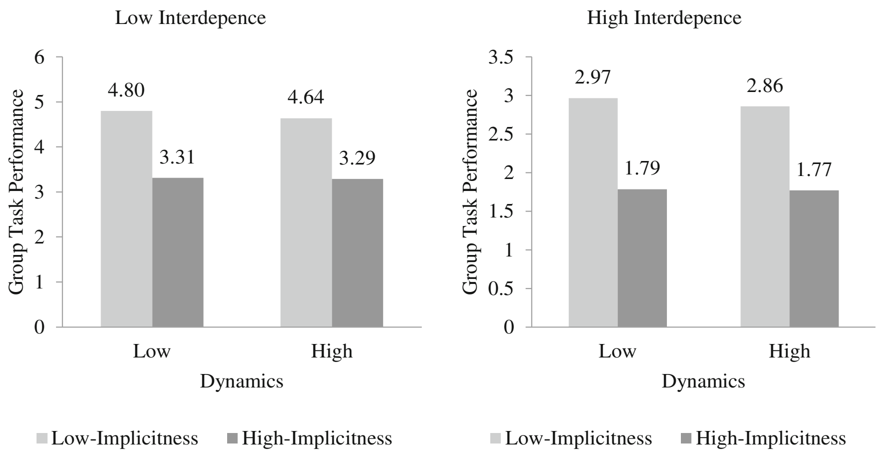

Fig. 12.2 Three-way interaction of interdependence, dynamics, and implicitness

Previous studies mainly regarded TMS as a coordination mechanism of information. The information in a TMS has several characteristics: first, the information sharing does not cause any loss to the information providers; second, the information can be used by receivers without any transformation cost; third, the accuracy of information is easy to discern. Thus, the most important part of TMS development is to build a shared understanding of who knows what. Group members can get the information to finish subtasks as long as they find the right person. However, the multiactivity tasks that organizational workgroups engage in usually need to be accomplished by complex expertise. It is impossible to transfer some professional knowledge from one person to another in a limited time. In order to accomplish group task, experts from different areas often work together, which means that individual members serve as knowledge repositories [1]. In this process, the expertise is the exclusive resource that individuals utilize to fulfill the tasks by co-operating with others. Group members share with other parties the burden of loss or benefit of gain. Therefore, group members will cooperate with their most reliable persons.

Usually, group tasks determine what domains of knowledge are relevant. Group members first recognize which pieces of knowledge belong to which expertise. Then they determine that whom they should cooperate with according to the credibility of each person's expertise in their transacitve memory. Meanwhile, the credibility serves as a practical guide to other important group processes like knowledge refining. Thus, the first contribution of this paper is that we propose the effectiveness of a TMS in multiactivity task environment depends on the establishment and confirmation of credibility. Group member not only need to know who knows what but also to know who is more reliable to do what.

However, TMS is not useful for all types of tasks performed by workgroups in knowledge-based organizations. For a team that does not require diverse expertise or knowledge to do their work, it may not be necessary to develop a TMS [14].

Categorizing tasks allows us to systematically analyze the role of task type and to pinpoint more precisely how learning works when groups work on certain type of task [11]. Although the multiactivity task has been repeatedly stressed from theory to practice [14, 16, 21], the task attributes that matter most remain under theorized. Therefore, we focus our analysis on the attributes of multiactivity task. First, we view interdependence from the nature of task instead of the perception of group members which was widely used in previous studies. Second, we use dynamics to reflect the ever changing nature of the task demands caused by the change of broader organizational systems or performance environments. Third, as far as we know, this is the first study distinguishing the tacit and explicit knowledge in TMS research. Thus, our second contribution lies in summarizing the interdependence, dynamics, and implicitness attributes of multiactivity task, and demonstrates that the main effects and three-way interaction are all negatively related to group task performance.

This study makes the third contribution by developing a new agent-based simulation model to reflect the dynamic evolution process of TMS. Ren et al. [23] developed a multi-agent system named ORGMEM to investigate the effects of TMS on performance dependent on the organizational context and on team size. The most glaring weakness of their model is that all the simulated agents, resources, and tasks begin with a particular design, which greatly limits the stability and repetition of their model. In addition, Palazzolo and Serb [20] developed a simulation model to study the effects of initial knowledge, initial accuracy of expertise recognition, and network size on the development of a TM system as mediated through communication. They developed the simulation model by Blanche, which was a software package designed to create and execute computational models of network behavior. Although it is relatively easy to do simulation based on the mature software, the generality of those models is low. Our model overcomes above-mentioned shortcomings. It can clearly reflect how TMSs develop and evolve over time. This model can be used to investigate a complex set of factors that might affect the TMS evolution processes.

However, our study suffers from several limitations. First, because some scholars put forward that the TMS is an important component of group learning [8], and group learning processes are distributed across organizational members in a well-developed TMS [1], group learning should be another important indicator of group performance. Thus, task performance and group learning are not conflicting but complementary. On the one hand, some change in the group's range of potential behavior constitutes an evidence of group learning, but it is not manifested in external performance [26]. On the other hand, many factors that influence group learning (e.g. turnover) are also likely to impact group performance via mechanisms other than learning [10]. We deem that these two group performance indicators can reflect how task attributes affect group performance through TMS in a multiactivity task environment more completely. Second, we only consider the knowledge learning and TMS sharing in the model. During the interaction with others, group members can not only learn expertise knowledge but also develop the credibility of each person's expertise in their transacitve memory. Thus, the question that how the sharing of transactive memory affects group performance should be answered in future studies.

Third, more detailed indicators should be developed to measure TMS in the model. We only analyze the mediation effect of TMS between multiactivity task attributes and group task performance in theory. More specific mechanism should be investigated in future studies. Last, although the computer simulation method has high level internal validity, the results developed from our model still need to be further tested studies conducted in laboratory or field settings.

In conclusion, our paper provides an optimistic answer on how a TMS works in a multiactivity task environment. We propose that the development of TMS, an ongoing feed forward and feedback process to improve group performance, largely depends on the establishment and confirmation of credibility in group members' transactive memory. Our results suggest that all three attributes of multiactivity tasks (interdependence, dynamics, and implicitness) have negatively influences on group task performance in different degrees. In order to overcome the detrimental influence, managers should not only promote group members share understanding of who knows what, but also provide opportunities for gaining understanding of who is reliable to do what.

Acknowledgments This work was supported by National Natural Science Foundation of China (Grant No. 71302170; 71302119), and MOE (Ministry of Education in China) Project of Humanities and Social Sciences (Project No. 13YJC630036).

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Chapter 13
Research on the Construction Safety Investment Regulation Evolutionary Game and Application

Wenke Wang, Qin Yang, Mao Lu and Qiaoyan Yu

Abstract From the view of limited rationality, the interaction behavior between construction safety supervision departments and construction enterprises is analyzed based on evolutionary game theory. An evolutionary game model of the safety investment supervision in construction enterprise is established. The replication dynamic equation and the dynamic evolution process of the both gaming parties are analyzed. The behavior features of the two gaming parties and the affect to the stability status are revealed. The different kinds of evolutionary stability strategies are analyzed and the long-time stable tendency of construction safety investment supervision is predicted. Besides, the article provides empirical studies which prove that the model is more effective and verify the validity of the model. Article concludes with some policy recommendations. For construction enterprises safety investment and government supervision and management, the theoretical and methodological useful guide is provided.

Keywords Construction safety investment · Regulation · Evolution game · Stable strategy

13.1 Introduction

The healthy and sustainable development of construction industry is the important guarantee of economic development in China. For the construction industry, the ensurance of production safety is an important responsibility of the government and construction enterprises [11]. Construction safety situation of our country has

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_13,

greatly improved through the efforts of government and enterprise in recent years, but currently there are still some problems of frequent safety accidents [5] and greater casualties [3]. For construction enterprises, the emphasis and implementation of safety investment is the prerequisite to actualize safety production, and it is also the important guarantee of realizing economic and social benefits and sustainable development. However, due to the high cost and low profit of construction enterprises, along with inadequate government supervision, they lead to the current construction enterprises not having enough impetus to implement security investment, which is difficult to guarantee the production and development of health and safety in construction enterprises. The government has always been attaching great importance to the safety production of the construction enterprises [8], conducting policy guidance and supervision to the construction enterprise' safety production and investment. But as the result of the inadequacy of the current management system and indicators for performance check, and the insufficiency of regulatory enforcement, combined with the current management without fully considering the bounded rationality, there still exists the phenomenon that the construction safety investment supervision is insufficient. One question which has remained to be urgently solved is how the government supervisory department effectively regulates, guides and motivates construction enterprise safety investment.

13.2 Analysis Framework

The decision-making of construction enterprise itself and the regulation of the government will influence the safety investment of construction enterprises. Shenling analyzed the supervisory strategies of construction safety investment with the method of game [7]. Zhao and Yang analyzed the supervision status of coal mine safety production of our country according to the theory of game, finding that the government can effectively improve the efficiency of governance by means of increasing penalties for illegal enterprises, reducing regulatory costs, and enhancing the supervision probability [10]. Cao and Wang analyzed the regulation of construction safety production in our country and put forward the relevant policy recommendations by using the theory of game [2]. There are a lot of researches on construction safety investment regulations in recent literature from the macroscopic and microscopic view and the qualitative and quantitative perspective. But currently the construction companies and the government are analyzed as a perfectly rational object in the main study, and the limited rationality of the construction enterprises and the government is not considered in the process of government regulation of construction enterprises safety investment. With consideration of the limited rationality of the government and enterprises, it is of great practical significance for the government to implement effective supervision and further to promote the construction safety investment and the safety production level. In the process of dealing with limited rationality game, evolutionary game [1] which is based on limited rationality [6] can effectively manipulate the evolutionary process of both sides, imitating gradually by

Table 13.1 One safety investment regulation game model of construction enterprises

Construction enterprise	Government regulator	
	Regulation x	No regulation $1-x$
Safety investment y	$R-I$	$R-I$
	$-A$	0
Illegal production $1-y$	$R-pL-qF$	$R-pL$
	$qF-A$	$-p(C+M)$

the most advantageous strategy, eventually reach an equilibrium state [4] and obtain the credible conclusions closer to the reality.

Therefore, the paper studies the regulation of construction safety investment applying the evolutionary game theory to help the government make a scientific and effective regulatory decision-making and system design in the process of government regulation. It is of great practical significance for the healthy and sustainable development of construction enterprises and to promote the implementation of construction enterprise safety investment more effectively.

13.3 Foundational Assumptions of Evolutionary Game Model of Safety Investment Regulation

For construction safety investment regulation, there is game between government regulators and construction companies, and the both sides have their own different strategy choice. As the government regulators, they can choose to supervise or not, while for construction enterprises correspondingly, they can choose to implement safety investment or not. The strategy and income of both sides are asymmetric on their different options, whose payoff matrix are shown in Table 13.1.

As is shown in the Table 13.1, the character A stands for government regulation costs. Due to the limitation of various conditions, government regulators can only implement regulation work with probability x. If the construction enterprises realize that the implementation of construction safety investment is of great importance for the stable and healthy development of the enterprise, the construction enterprises will implement safety investment without considering regulation or not, I standing for the safety investment cost. R stands for the comprehensive benefit obtained by construction enterprise in safety production, the probability of which is y. If construction enterprises ignore safety production and abandon safety production investment in order to get maximum benefit, p stands for probability for construction safety accident, L for the loss of the accident. F stands for penalty once the problems and accidents were discovered by government regulators, and q for the probability of being punished. If regulators do not supervise the safety production of the construction companies diligently, therefore construction companies do not pay attention to the construction safety investment. Once the safety accidents happened, which causes the social cost C, regulators can receive the penalty M caused by the superior government.

13.4 Analysis of Evolutionary Game of Construction Safety Investment Regulation

With the slow strategy study and slight headway of dynamic adjustment of construction safety investment and regulatory, the replication dynamics can be applied to study the interactive game of the construction safety investment regulation by using evolutionary game to analyze construction safety investment regulation [9].

13.4.1 Replication Dynamics and Stable Strategy of Evolutionary Game of Construction Safety Investment

From the Table 13.1, the return for the implementation of safety investment of construction enterprises is $u_1 = x(R-I)+(1-x)(R-I) = R-I$. The return without the implementation of safety investment of construction enterprises is $u_2 = x(R-pL-qF)+(1-x)(R-pL) = R-pL-xqF$. The average return for construction enterprise groups is $\bar{u} = yu_1 + (1-y)u_2 = y(pL-I+xqF)+R-pL-xqF$. The replication dynamic equation of construction enterprises on safety investment behavior is: $F(y) = \frac{dy}{dt} = y(u_1-\bar{u}) = y(1-y)(pL-I+xqF)$.

Making $F(y) = \frac{dy}{dt} = 0$, the possible stable state is:

$$y_1 = 0,\ y_2 = 1,\ x = \frac{I-pL}{qF}. \tag{13.1}$$

As is known by the nature of the evolutionary stable strategy, when $F'(y^*) < 0$, y^* is the evolutionary stable strategy.

- When $x = \frac{I-pL}{qF}$, $F(y)$ is 0. At the moment, government's regulation reaching $x = \frac{I-pL}{qF}$, the initial ratio between implementation of safety production investment and no implementation of safety production investment in any construction enterprises is stable.
- When $x \neq \frac{I-pL}{qF}$, there are two balance points $y_1 = 0$, $y_2 = 1$, of Replication dynamic equation.
- When $x > \frac{I-pL}{qF}$, $F'(1) < 0$, that is $y_2 = 1$ which is the evolutionary stable strategy. After a long repeated game, limited rational construction enterprises choose to implement safety investment strategy to strengthen the importance of construction safety investment.

- When $x < \frac{I-pL}{qF}$, $F'(0) < 0$, that is $y_1 = 0$ which is the evolutionary stable strategy. After a long repeated game, limited rational construction enterprises choose not to implement safety investment strategy. In this case, the construction enterprises will gradually reduce emphasis on safety investment.

13.4.2 Replication Dynamics and Stable Strategy of Evolutionary Game of Government Regulation

From the Table 13.1, government regulators' return for supervision is $n_1 = y(-A) + (1-y)(qF - A) = (1-y)qF - A$. And government regulators' return without supervision is $n_2 = -p(1-y)(C+M) = p(y-1)(C+M)$. The average return of the government regulators is $\bar{n} = xn_1 + (1-x)n_2 = x[(1-y)qF - A] + (1-x)p(y-1)(C+M)$. Replication dynamic equation of government regulators is $H(x) = \frac{dx}{dt} = x(n_1 - \bar{n}) = x(1-x)[(1-y)(qF + pC + pM) - A]$.

Making $H(x) = \frac{dx}{dt} = 0$, the stable state is:

$$x_1 = 0, x_2 = 1, y = 1 - \frac{A}{qF + p(C+M)}. \tag{13.2}$$

As is known by the nature of the evolutionary stable strategy, when $H'(x^*) < 0$, x^* is the evolutionary stable strategy.

- When $y = 1 - \frac{A}{qF+p(C+M)}$, $H(x)$ is 0. That is, when construction enterprises put safety investment value to $y = 1 - \frac{A}{qF+p(C+M)}$, the intensity of government regulation is stable.
- When $y \neq 1 - \frac{A}{qF+p(C+M)}$, replication dynamic equation has two balance points $x_1 = 0, x_2 = 1$.
- When $y > 1 - \frac{A}{qF+p(C+M)}$, $H'(0) < 0$, that is, $x_1 = 0$ is the evolutionary stable strategy. The construction enterprises actively implement the safety investment and government regulators have fewer regulations.
- When $y < 1 - \frac{A}{qF+p(C+M)}$, $H'(1) < 0$, that is, $x_2 = 1$ is the evolutionary stable strategy. In this case, limited rational construction enterprises choose not to implement safety investment strategy and government regulators actively implement safety regulation.

13.5 Game Theory Analysis

Making $x^* = \frac{I-pL}{qF}$, $y^* = 1 - \frac{A}{qF+p(C+M)}$. As is shown in Fig. 13.1, the replication dynamic and game tendency of security investment regulation in construction companies and government regulators are drawn.

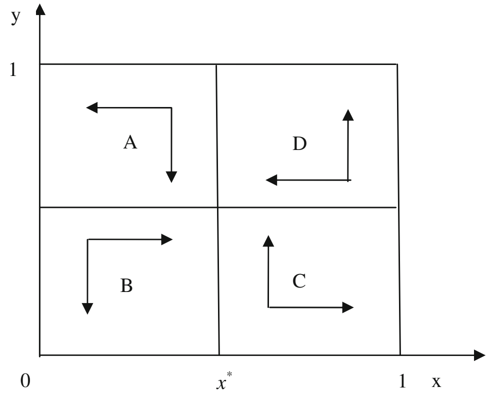

Fig. 13.1 Construction safety supervision game phase diagram

Government regulator and construction companies both are not have the only dominant strategies, the system' converge depends on its initial state. When the initial strategy falls into area A, construction companies would choose "implementation of safety investment" strategy, and government regulators select "no regulation" strategy. But this relationship is not stable. In fact, if government regulators select "no regulation" strategy, then the construction enterprises will tend to choose "not to implement" strategies. It will lead the strategic profile to fall into the area B, in which government regulators choose "no regulation" strategy and construction enterprise choose "not to implement" strategies. Because groups will gradually adjust their strategies by mutual learning in B region, this state is not stable obviously. When government regulators realized that construction companies select "not to implement" strategies, they will gradually adjust their strategy to fall into the area C, in which government regulators will choose "regulation" strategy. In this case, faced with the "regulation" strategy, construction companies will gradually adjust their strategy to fall into the area D, in which the construction companies select "implementation of safety investment" strategy and government regulators choose "regulation" strategy. In this case, government regulators found that construction companies have chosen "implementation of safety investment strategy", they will gradually adjust their strategy to fall into "no regulation" strategy which is the area A. The cycle of the preceding process continues.

Firstly, for the government regulator, the increase of regulatory cost A will make y^* decrease, which causes construction enterprises to attach less importance to construction safety investment. For another, with the increase of C and M, y^* will increase. Government regulators will enhance supervision intensify and probability under the pressure from social expectations and the superior government.

Secondly, for construction companies, when the government supervision probability satisfies $x > x^*$, construction enterprises will attach greater importance to the safety investment; if F increases, y^* will also go up. That is, construction enterprises will attach more importance to construction safety investment when regulators

Table 13.2 Strategies of safety investment regulation for construction enterprises

Construction enterprises	Government regulator	
	Regulation	No regulation
Safety investment	1,200	1,200
	−200	0
Illegal production	1,010	1,360
	150	−360

give them more punishments. Of course, the increase of R will lead to the increase of I and the decrease of F. If construction enterprises increase construction safety investment, they will enhance the comprehensive benefits R, meanwhile, reduce the negative benefits F, which makes the government regulation intensity will also be reduced.

13.6 Calculation Case Analysis

The government regulatory cost A is 2 million yuan. The cost I of construction enterprise safety investment is 8 million yuan, while the comprehensive benefits R of construction enterprise safety production are 20 million yuan. The probability p of accidents should be 0.8 when the investment of safety production is not implemented by construction enterprises and the loss L after the accident is 8 million yuan. The penalties F will be 5 million yuan once the accident is found by the government regulators with the probability $q = 0.7$. If the construction enterprises do not implement the construction safety investment because of the shortage of the government supervision, the social cost C will arrive at 300 million yuan caused by the accidents, and the penalties M on regulators are 150 million yuan caused by the superior government. The government regulator and construction enterprises game model are shown in Table 13.2.

Data below can be calculated according to the Eq. (13.1): $x = \frac{I-pL}{qF} = \frac{800-0.8\times 800}{0.7\times 500} = 0.46$. From the Eq. (13.2), we can obtain: $y = 1 - \frac{A}{qF+p(C+M)} = 1 - \frac{200}{0.7\times 500+0.8(300+150)} = 0.72$.

From the model analysis we can make a conclusion that when government's regulation reaching $x = 0.46$, the initial ratio between implementation of safety production investment and no implementation of safety production investment in any construction enterprises is stable.

- When $x > 0.46$, after a long repeated game, limited rational construction enterprises choose to implement safety investment strategy to strengthen the importance of construction safety investment.
- When $x < 0.46$, after a long repeated game, limited rational construction enterprises choose not to implement safety investment strategy. In this case, the construction enterprises will gradually reduce emphasis on safety investment.

For construction enterprise, when construction enterprises put safety investment value to $y = 0.72$, the intensity of government regulation is stable.

- When $y > 0.72$, The construction enterprises actively implement the safety investment and government regulators have fewer regulations.
- When $y < 0.72$, limited rational construction enterprises choose not to implement safety investment strategy and government regulators actively implement safety regulation.

13.7 Conclusions

It is the important guarantee for construction enterprises sustainable development to make effective supervision on construction safety investment. From the view of limited rationality, the interaction behavior between construction safety supervision departments and construction enterprises is analyzed based on evolutionary game theory. An evolutionary game model of the safety investment supervision in construction enterprise is established. The behavior features of the two gaming parties and the affect to the stability status are revealed. The different kinds of evolutionary stability strategies are analyzed and the long-time stable tendency of construction safety investment supervision is predicted. For construction enterprises safety investment and government supervision and management, the theoretical and methodological useful guide is provided. Based on the research result of this paper, we can make the conclusion and the policy suggestions as follows:

1. To make the entire construction industry health and sustainable development, the government should strengthen the supervision and punish illegal enterprises severely by legislation to make sure the safety investment.
2. The supervision departments of the government should keep on improving the efficiency of supervision and reducing the cost of supervision including the running cost of the regulator.
3. The cost of construction enterprises who never comply with the safety production of construction and implement safety investment should be increased by policy and regulation. Meanwhile, the cost of safety investment should be decreased to lead and impel construction enterprises to implement the safety investment.
4. The assessment and the accountability system of supervision department should be strengthened; meanwhile the public should be encouraged to actively participate in supervision. The supervision is not only for the construction enterprises but also for the government regulator.

Acknowledgments The research is funded by "The Department of Education Project of Sichuan Province (14SB0022): Research on Enterprise Safety Investment System Analysis and Multi-regulatory Game", "Sichuan Province, Philosophy and Social Science Research Base—Sichuan Mineral Resources Research Center Funded Projects (SCKCZY2012-YB005)" and "The Department of Education Key Project of Sichuan Province (14ZA0026)" and "The Sichuan Normal University Project (14yb18)".

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Chapter 14
A Rumor Spreading Model Considering Latent State

Yi Zhang and Chong Chen

Abstract In this paper, a variant of the SIR model for rumor spreading is proposed. The model adds an additional group called lurker that considers some more realistic characteristics of rumor spreading. That is, the judgment state on rumor and memory effect are considered in our model. In stability analysis, we proved that differential equations is asymptotically stable at the zero solution which shows our model has a good stability. In addition, we conduct sensitivity analysis of model and analyze the influence of various parameters on the rumor transmission process. The simulation results show that our model accords with the rumor spreading process, and the parameter p_1 is helpful to the rumor spreading, the p_2 and p_3 play a positive role in stifling the spreading of rumor.

Keywords Lurker · Rumor spreading · Simulation

14.1 Introduction

Rumor spreading has a significant impact on human society and has attracted a lot of attention in recent years. Although there are many different versions of the definition rumors [6]. In 1947, Allport and Postman analyze the factors affecting the rumor and give formula [1] which shows that the more important and obscure, the greater

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_14,

effect of rumor. As an important part of people's lives, rumor spreading can shape public opinion, and cause social panic and instability [5, 9, 15], what's worse, with the emergence of online social network, the spreading of rumors is faster and wider than ever before.

The research results of rumor spreading mainly focuses on rumor spreading model. Most of the existing models of rumor spreading are variants of SIR epidemic models [4, 7], because rumor spreading shows great similarities to the epidemic spreading. In the early stage, the DK models [2, 3] use stochastic process method to analyze the rumors, which is a abstract mathematical model. Sudbury [11] studied the dynamic behavior of rumor spreading using the SIR model earliest. Then Zanette [16, 17] established a rumor spreading model on small-world networks. Moreno et al [8] studied rumor spreading model on scale-free networks and compared the results get by computer simulation and stochastic analysis method. Novel models and tools appeared recently considering network topology. The literature [12] propose a novel model based on the physical theory and make comparison experiments to contrast the proposed model with the traditional models. Zhao did a lot of research variants of SIR epidemic models [13, 14]. Although there are many similarities between epidemic spreading and rumor spreading, there are essential differences between them. In the process of spreading of rumor, people do not spread the rumor at once after they get the information, people will judge the authenticity of information through their cognition. The entire population is divided into three groups that are susceptible (those who never heard rumor)—infected (the people who are spreading rumor)—recovered (he ones who heard rumor but do not spread it) in most of rumor spreading models. But this classification cannot show the nature of the rumors spreading.

In this paper, we add an additional group called lurker in our model, and we propose a variant of the SIR model for rumor spreading. This model can well depict the rumor spreading process in the social network. In Sect. 14.3, we conduct the stability analysis of the model, we proved that differential equations is asymptotically stable at the zero solution by using variables separation in the stability theory. In Sect. 14.4, we analyze the characteristic of susceptible, exposed, infected and recovered in whole spreading process. And we verify that the model can represent propagation behavior of rumor. In addition, we apply the model and compare the the densities of spreaders and stiflers change over time for different p_1, p_2, p_3.

14.2 Model

Although rumor spreading shows great resemblance to that of epidemics, rumor spreading is significantly different from epidemic spreading as individuals can decide to spread rumor whether or not. In the process of dissemination of rumor people will judge the authenticity of information through their cognition after getting the information. we called this process is latency period. We borrow the model of epidemics spreading and modified it making fit the feature of rumor spreading. Considering a network with N nodes and E links representing the individuals and their

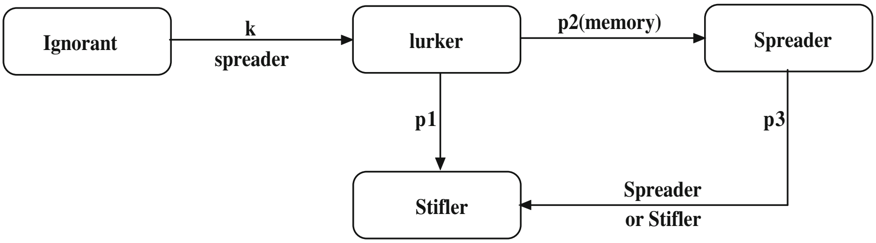

Fig. 14.1 Structure of rumor spreading process

interactions. At each time step, each individual adopts one of four states: (1) Ignorant (the Susceptible)—the individual has not yet heard the rumor. (2) lurker (the Exposed)—the individual know this rumor, but willing to spread the rumor because he require active effort to discern between true and false. (3) spreader (the Infected)—the individual know this rumor, and transmit the rumor to all her neighbors. (4) stifler (the Removed)—the individual never trust the rumor and transmit this rumor again.

We assume that the rumor is disseminated by direct contacts of spreaders with others, and the process of rumor spreading is shown in Fig. 14.1. As shown in Fig. 14.1 ignorants, lurker, spreader and stiflers in the network follow the rules: (1) When an ignorant contacts a spreader, the ignorant becomes a lurker with probability 1, the contacting probability k is decided by the specific network topology. (2) A lurker become a spreader at the rate of p_1, and become a stifler at the rate of p_2. (3) When a spreader contact another spreader or a stifler, the initiating spreader becomes a stifler at a rate q. When two spreaders contact with each other, both of them may find two pieces of information is not inconsistent, so they stop spreading. When a spreader contacts a stifler, the spreader tries to remove it, because the stifler shows no interest in it or denies it. As a result, the spreader becomes a stifler with the probability p_3.

Denote by $S(t)$, $E(t)$, $I(t)$, $R(t)$ the density of Ignorants, Lurker, Spreaders), Removed at time t, and $S(t)$, $E(t)$, $I(t)$ and $R(t)$ represent the density of Ignorants, Lurker, Spreaders, and Stiflers at time t. In addition, $S(t) + E(t) + I(t) + R(t) = 1$. Considering in the homogeneous network, the mean-field equations read as:

$$\frac{dS(t)}{dt} = -kS(t)I(t), \tag{14.1}$$

$$\frac{dE(t)}{dt} = kS(t)I(t) - p_1E(t) - p_2E(t), \tag{14.2}$$

$$\frac{dI(t)}{dt} = p_1E(t) - kp_3I(t)(I(t) + R(t)), \tag{14.3}$$

$$\frac{dR(t)}{dt} = kp_3I(t)(I(t) + R(t)) + p_2E(t). \tag{14.4}$$

14.3 Steady-State Analysis

In rumor spreading process, the system has only ignorants, spreaders firstly. Finally, the system has only ignorants and stiflers reaches an equilibrium state. So we analyze the system's steady-state in following period.

Substituting $I(t) + R(t) = 1 - S(t) - E(t)$ into the differential Eq. (14.3), the differential Eqs. (14.1)–(14.3) has nothing to do with the $R(t)$, so we only consider the these three equations. Then the reduced limiting dynamical system is given by:

$$\frac{dS(t)}{dt} = -kS(t)I(t), \tag{14.5}$$

$$\frac{dE(t)}{dt} = kS(t)I(t) - p_1E(t) - p_2E(t), \tag{14.6}$$

$$\frac{dI(t)}{dt} = p_1E(t) - kp_3I(t)(1 - E(t) - S(t)). \tag{14.7}$$

Theorem 14.1 *Differential Eqs. (14.5)–(14.7) has infinite zero solution.*

Proof Letting the right side of each of the differential Eqs. (14.5)–(14.7) be equal to zero in system gives the equation:

$$-kS(t)I(t) = 0, \tag{14.8}$$

$$kS(t)I(t) - p_1E(t) - p_2E(t) = 0, \tag{14.9}$$

$$p_1E(t) - kp_3I(t)(1 - E(t) - S(t)) = 0. \tag{14.10}$$

The feasible region for equations is R^3, and we study equations in closed set $A = \{(S, E, I) \in R^3 | S + E + I \leq 1, S, E, I \geq 0\}$.

From Eq. (14.9), we can get $(p_1 + p_2)E(t) = 0$, so $E = 0$, substituting $E = 0$ into the Eq. (14.10), we have $kp_3I(t)(1 - S(t)) = 0$. Adding Eq. (14.8), we can get $I(t) = 0$. From the Eq. (14.8), so the system has the equilibriums $P^* = (S, E, I) = (S^*, 0, 0)(0 \leq S^* \leq 1)$.

Now, we conclude that differential equations has infinite singularity.

Theorem 14.2 *The equilibrium P^* is asymptotically stable.*

Proof Let Liapunov function is $V(S, E, I) = F(S) + G(E) + H(I)$. Taking the drivative of V versus t along the solution of equations, we have:

$$\begin{aligned} V'(S, E, I) = &-F'(S)kS(t)I(t) + G\prime(E)[kS(t)I(t) - p_1E(t) - p_2E(t)] \\ &+ H\prime(I)[p_1E(t)I(t) - kp_3I(t)(1 - E(t) - S(t))]. \end{aligned}$$

In order to ascertain $V(S, E, I)$ and $V'(S, E, I)$, take the value $F'(S) = 1$, $G'(E) = 1$, $H'(I) = 1$, we can get $V(S, E, I) = S + E + I$, and

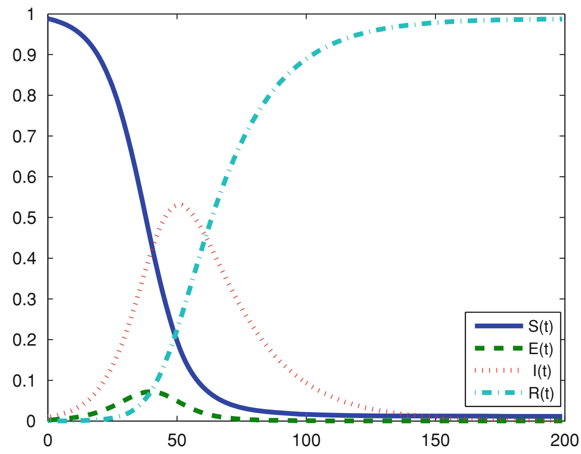

Fig. 14.2 Densities of ignorants, spreaders, lurkers, and stiflers over time

$$V'(S, E, I) = -kS(t)I(t) + kS(t)I(t) - p_1E(t) - p_2E(t) + p_1E(t) - kp_3I(t)$$
$$(1 - E(t) - S(t)) = -p_2E(t) - kp_3I(t)(1 - E(t) - S(t)) \leq 0.$$

So we can get $V(S, E, I)$ is Positive definite and $V'(S, E, I)$ is negative semidefinite in the feasible region $A = \{(S, E, I) \in R^3 | S + E + I \leq 1, S, E, I \geq 0\}$.

$\{(S, E, I)|V'(S, E, I) = 0, (S, E, I) \in A\}$ does not contain the equations' whole trajectory, so zero solution P^* is asymptotically stable.

14.4 Results

We solve the differential Eqs. (14.1)–(14.4) using the Runge-Kutta method and analyze the effects on the rumor spreading process by the factors. In the following simulation, the given parameters value, $S = 0.99,\ E = 0,\ I = 0.01,\ R = 0,\ k1 = 0.16,\ p_1 = 0.01,\ p_2 = 0.4,\ p_3 = 0.3$.

Figure 14.2 shows the general trends of the four kinds of agents in the rumor spreading model on regular networks. We can find that the number of spreader increases sharply at the beginning of the process. With further spreading of the rumor, the number of spreaders reaches a peak and decreases as time goes on. Finally, the number of spreaders is zero and spreading of rumor is terminated. The variation of the number of lurker is similar to that of spreader, but the number of lurker has much less change and the peak value of the $E(t)$ smaller than that of $I(t)$. With the increase of time t, the number of ignorants $S(t)$ always reduces while the number of stiflers $R(t)$ always increases, and they reach the balance at the end of rumor spreading process. From the figure, the number of the spreader is largest at the time of 50.4608, which is equal to 0.5307, and all agents become stifler about at the time of 200.

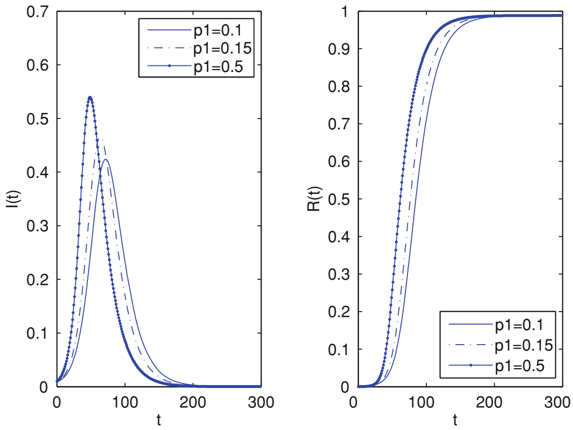

Fig. 14.3 Densities of spreaders, stiflers with different probability p_1

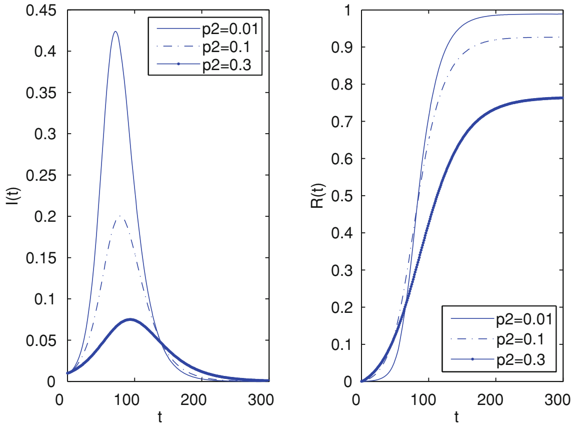

Fig. 14.4 Densities of spreaders, stiflers with different probability p_2

Figure 14.3 shows how the densities of spreaders and stiflers change over time for different memory rate p_1. The bigger of the rate p_1, the greater of the number of spreader $I(t)$, and $I(t)$ reaches the peak earliest. The number of the stifler increases faster with the increase of the parameter of p_1 in the early of the spreading process. Surprisingly, the influence of the final scale of the $R(t)$ is not affected by the change of the p_1. These results can be interpreted as follows. As shown in Fig. 14.1, when the memory rates are bigger, the number of the lurkers becoming the spreader is more. Thus more spreaders disseminate the rumor, which makes the the final rumor size larger.

Figure 14.4 shows how the densities of spreaders and stiflers change over time for different p_2. With the increase of p_2, the number of spreaders reach the peak later, and the peak value is smaller. At same time, we can find the final rumor size is smaller when p_2 is bigger. The range of $I(t)$ is greater when p_2 have bigger change. For example, $R(t) = 0.7675$ when $p_1 = 0.1$, it shows that nearly 0.2225 of whole

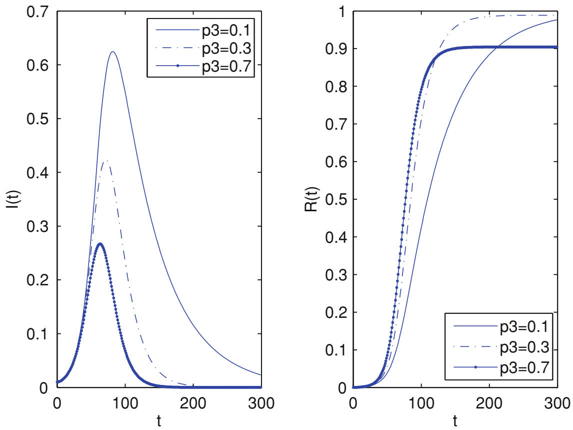

Fig. 14.5 Densities of spreaders, stiflers with different probability p_3

population never heard rumors. Due to different cultural background of people, the parameter p_2 is different in different type of networks.

We investigate how the $I(t)$ and $R(t)$ changes with the stifling rate p_3. Figure 14.5 reveals that stifling probability has a significant influence on rumor spreading. The less the stifling probability p_3, the larger the final size of a rumor R. We are aware that more spreaders stop transmitting the rumor due to the bigger stifling rate, the influence of the rumor becomes weaker.

14.5 Conclusions

In this paper, we propose a rumor spreading model with lurker that considers some more realistic characteristics of rumor spreading. We conduct sensitivity analysis of model and analyze the influence of various parameters on the rumor transmission process. In stability analysis, we proved that differential equations is asymptotically stable at the zero solution by using variables separation in the stability theory. In proving process, we know the equations have good stability, and stable point fits well with rules of rumors spread in reality. In addition, we conduct the numerical simulation for the mean-field equations of the model. The simulation results show that the parameter p_1 is helpful to the rumor spreading. The bigger of the rate p_1, the greater of the number of spreader $I(t)$. At same time, the p_2 and p_3 play a positive role in stifling the spreading of rumor. We can find the final rumor size is smaller when p_2 is bigger. For the parameter p_3, we can get some result.

In the future, further study will be conducted with the cumulative effect of memories on the spread of rumors, because remembering mechanisms is the repeated characteristic of the rumor. We will extend our research to the heterogeneous network and real online social network.

Acknowledgments This research was supported by Major Bidding Program of the National Social Science Foundation of China (Grant No. 12&ZD217), and supported by Natural Science Foundation of Anhui Province (Grant No. KJ2011B140). We are very appreciated for its support in finance and in spirit.

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Chapter 15
Linguistic Distribution Assessments with Interval Symbolic Proportions

Yuzhu Wu, Hengjie Zhang and Yucheng Dong

Abstract In linguistic distribution assessments, symbolic proportions are assigned to all the linguistic terms. As a natural generation, we propose the concept of distribution assessments with interval symbolic proportion in a linguistic term set, and then study the operational laws of linguistic distribution assessments with interval symbolic proportion. Then, the weighted averaging operator and the ordered weighted averaging operator for linguistic distribution assessments with interval symbolic proportion are presented. Finally, two examples are presented for demonstrating the applicability of the proposed approach for computing with words.

Keywords Computing with words · Linguistic distribution assessments · Interval symbolic proportion · Aggregation operators

15.1 Introduction

In day-to-day activities we have to solve different decision problems that are complex to assess by means of precise and exact values. When using linguistic approaches to deal with such decision problems, the techniques for computing with words (CW) [4, 8, 10, 14, 15, 20] are needed. Herrera [6] and Martínez [12] surveyed that there are three linguistic computational models: (1) the model based on extension principle [1, 5]; (2) the symbolic model [3]; (3) the model based on linguistic 2-tuples [6, 11]. The results of the former two models both produce a consequent loss of information and the lack of precision.

In [6], Herrera and Martínez proposed the notable 2-tuple fuzzy linguistic representation model and defined the corresponding computational 2-tuple. Based on the 2-tuple linguistic representation model, Herrera and Martínez [7] further developed

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_15, © Springer-Verlag Berlin Heidelberg 2014

a linguistic decision model dealing with multi-granular linguistic contexts in the linguistic hierarchy structure. A recent overview on the 2-tuple linguistic model can be found in [12]. Although the Herrera and Martínez model has no loss of information, it only suited for dealing with uniformly and symmetrically distributed linguistic term sets. And in real decision-making environment, the linguistic term sets are not uniformly and symmetrically distributed.

In order to deal with linguistic term sets that are not uniformly and symmetrically distributed, numerous decision making models based on unbalanced linguistic term sets have been presented. For example, Cabrerizo et al. [2] presented a consensus-based group decision making with unbalanced linguistic terms. Based on the concepts of symbolic proportion and the canonical characteristic values (CCVs) of linguistic terms, Wang and Hao [17, 18] extended the Herrera and Martínez [6] model, and provided a new model (i.e., the proportional 2-tuple fuzzy linguistic representation model) for CW, where symbolic proportions are assigned to two successive ordinal terms in a linguistic term set. Zhang et al. [21] further proposed the concept of distribution assessment in a linguistic term set, where symbolic proportions can be assigned to all the linguistic terms for distribution assessments in a linguistic term set.

However, although the models in [17, 18, 21] can deal with the linguistic term sets that are not uniformly and symmetrically distributed, the symbolic proportions are exact values. Generally, in some situations, it is hard and unrealistic for decision makers to provide the exact symbolic proportions. As a result, a better approach is to use symbolic proportions to deal with this issue. Inspired by the idea, we present the distribution assessments with interval symbolic proportions for overcoming this limitation.

The main aim of this paper is to propose the concept of distribution assessments in a linguistic term set with interval symbolic proportion, based on the Zhang et al. [21] model. The rest of the paper is arranged as follows. Section 15.2 introduces the basic knowledge regarding the linguistic models and interval arithmetics. The operational laws of distribution assessments with interval symbolic proportion are proposed in Sect. 15.3. Following this, two illustrative examples are provided in Sect. 15.4. Finally the concluding remarks are included in Sect. 15.5.

15.2 Preliminaries

This section introduces the basic knowledge regarding 2-tuple fuzzy linguistic representation model, proportional 2-tuple fuzzy linguistic model and interval arithmetics.

15.2.1 2-Tuple Fuzzy Linguistic Representation Model

Let $S = \{s_i | i = 0, \cdots, g\}$ be a linguistic term set with odd cardinality. The term s_i represents a possible value for a linguistic variable, and it is required that the linguistic term set should satisfy the following characteristics.

Definition 15.1 [6] Let $\beta \in [0, g]$ be a real number in the granularity interval of the linguistic term set $S = \{s_0, \cdots, s_g\}$, and let $i = \text{round}(\beta)$ and $\alpha = \beta - i$ be two values such that $i \in [0, g]$ and $\alpha \in [-0.5, 0, 5)$. Then, α is called a symbolic translation, with round being the usual rounding operation.

Definition 15.2 [6] Let $S = \{s_0, \cdots, s_g\}$ be as before and $\beta \in [0, g]$ be a value representing the result of a symbolic aggregation operation, the 2-tuple that express the equivalent information to β is obtained with the following function:

$$\Delta : [0, g] \rightarrow S \times [0.5, 0.5),$$
$$\Delta\beta = (s_i, \alpha) \text{ with } \begin{cases} s_i, & i = \text{round}(\beta) \\ \alpha = \beta - i, & \alpha \in [0.5, 0.5). \end{cases}$$

Clearly, Δ is a one to one mapping function. For convenience, its range is denoted as $\bar{S}$. Then, Δ has an inverse function with $\Delta^{-1} : \bar{S} \rightarrow [0, g]$ with $\Delta^{-1}((s_i, x)) = i + x$.

A computational model has been developed for the Herrera and Martínez model. Let (s_k, α_1) and (s_l, α_2) be two 2-tuples.

1. A 2-tuple comparison operator:
   a. if $k < l$, then (s_k, α_1) is smaller than (s_l, α_2);
   b. if $k = l$, then
      (i) $\alpha_1 = \alpha_2$, then (s_k, α_1), (s_l, α_2) represents the same information;
      (ii) $\alpha_1 < \alpha_2$, then (s_k, α_1) is smaller then (s_l, α_2).
2. A 2-tuple negation operator: $Neg((s_i, \alpha)) = \Delta(g - (\Delta^{-1}(s_i, \alpha)))$.
3. Some 2-tuple aggregation operators have been developed, such as the linguistic ordered weighted aggregation operator, the weighted average operator, the OWA operator, etc. (see [6]).

15.2.2 *Proportional 2-Tuple Fuzzy Linguistic Representation Model*

This subsection introduces the proportional 2-tuple fuzzy linguistic representation model proposed by Wang and Hao [17].

Definition 15.3 [17] Let $S = \{s_0, \cdots, s_g\}$ be a linguistic term set. $I = [0, 1]$ and $IS = I \times S = \{(\alpha', s_i) | \alpha' \in [0, 1], i = 0, 1, \cdots, g\}$.

Given a pair (s_i, s_{i+1}) of two successive terms of S, any two elements (α', s_i), (β', s_{i+1}) of IS is called a symbolic proportion pair and α', β' are called a pair of symbolic proportions of the pair (s_i, s_{i+1}), if $\alpha' + \beta' = 1$. A symbolic proportion pair (α', s_i), $(1 - \alpha', s_{i+1})$ will be denoted, $(\alpha' s_i, (1 - \alpha') s_{i+1})$, and the set of all the symbolic proportion pairs is denoted by $\bar{S}$, i.e.,

$$\bar{S} = (\alpha' s_i, (1 - \alpha') s_{i+1}) | \alpha' \in [0, 1], \ i = 0, 1, \cdots, g - 1.$$

The semantic of linguistic terms used in Wang and Hao's model is defined by symmetrical trapezoidal fuzzy numbers $T[b-\delta, b, c, c+\delta]$, which are varying in a 1-D characteristic. If the semantic of s_i is defined by $T[b_i-\delta_i, b_i, c_i, c_i+\delta_i]$, Wang and Hao suggested that the CCV of s_i is $(b_i+c_i)/2$. They extended CCV to $\bar{S}$ as follows.

Definition 15.4 [17] Let S, $\bar{S}$, and CCV on S be as before. For $(\alpha' s_i, (1-\alpha')s_{i+1}) \in \bar{S}$, the function CCV on $\bar{S}$ is:

$$\mathrm{CCV}(\alpha' s_i, (1-\alpha')s_{i+1}) = \alpha' \mathrm{CCV}(s_i) + (1-\alpha')\mathrm{CCV}(s_{i+1}).$$

A computational model has been developed for the Wang and Hao model, in which there exist the following.

1. A 2-tuple comparison operator: Let $(\alpha' s_i, (1-\alpha')s_{i+1})$ and $(\beta' s_j, (1-\beta')s_{j+1})$ be two proportional 2-tuples. Then:
   a. if $i < j$; then:
      (i) $(\alpha' s_i, (1-\alpha')s_{i+1})$, $(\beta' s_j, (1-\beta')s_{j+1})$ represents the same information when $i = j-1$, and $\alpha' = 0,\ \beta = 1$.
      (ii) $(\alpha' s_i, (1-\alpha')s_{i+1}) < (\beta' s_j, (1-\beta')s_{j+1})$, otherwise.
   b. if $i = j$; then
      (i) if $\alpha' = \beta'$, then $(\alpha' s_i, (1-\alpha')s_{i+1})$, $(\beta' s_j, (1-\beta')s_{j+1})$ represents the same information;
      (ii) if $\alpha' < \beta'$, then $(\alpha' s_i, (1-\alpha')s_{i+1}) > (\beta' s_j, (1-\beta')s_{j+1})$.
2. The negation operator over proportional 2-tuples: $Neg((\alpha' s_i, (1-\alpha')s_{i+1})) = ((1-\alpha')s_{g-i-1}, \alpha' s_{g-i})$.
3. Based on CCVs, Wang and Hao developed several weighted and ordered weighted aggregation operators of proportional 2-tuples as well.

15.2.3 Basic Interval Arithmetics

The interval arithmetics and their applications can be found in [12, 19]. An interval number can be denoted by $A = [a_L, a_R] = \{a | a_L \le a \le a_R, a \in R\}$, where a_L and a_R are the left and right limits of interval A on the real line R, respectively. If $a_L = a_R$, then A reduces to a real number.

Let A and B be two interval numbers. The extended addition and the extended subtraction are defined as follows: $A \oplus B = [a_L + b_L, a_R + b_R]$. If μ is a scalar, then

$$\mu \times A = \begin{cases} [\mu a_L, \mu a_R], & \mu \ge 0 \\ [\mu a_R, \mu a_L], & \mu < 0. \end{cases} \tag{15.1}$$

Several comparison operators between two interval numbers have been widely studied in [12, 13, 16]. We adopt Ishibuchi and Tanaka's [9] comparison operator here, that is:

$$A \leq B, \text{if } a_L \leq b_L, a_R \leq b_R; \; A < B, \text{if } a_L < b_L, a_R < b_R.$$

15.3 Distribution Assessment in a Linguistic Term Set with Interval Symbolic Proportion

This section proposes the concept of distribution assessment in a linguistic term set with interval symbolic proportion and the corresponding operational laws.

Definition 15.5 Let $S = \{s_0, \cdots, s_g\}$ be as before, let $m = \{(s_k, p_k)|k = 0, \cdots, g\}$, where $s_k \in S$, $p_k \geq 0$, and $p_k \in [\underline{p}_k, \overline{p}_k]$, p_k is the interval symbolic proportion of s_k, and $0 \leq \underline{p}_k \leq \overline{p}_k \leq 1$, then we call m the linguistic distribution assessment with interval symbolic proportion.

Note 15.1 Above, $\underline{p}_k$ and $\overline{p}_k$ are the left and right limits of interval p_k on the real line R, respectively. If $\underline{p}_k = \overline{p}_k$, then p_k reduces to a real number. According to [17], we normalize the interval symbolic proportion p_k if and only if:

$$\sum_{k=0}^{g} \overline{p}_k - \max_t (\overline{p}_t - \underline{p}_t) \geq 1, \; \sum_{k=0}^{g} p_k + \max_t (\overline{p}_t - \underline{p}_t) \leq 1, \; k, t = 1, \cdots, g; k \neq t,$$

which can be equivalently rewritten as:

$$\underline{p}_k + \sum_{t=1, t\neq k}^{g} \overline{p}_t \geq 1, k = 1, \cdots, g, \quad \overline{p}_k + \sum_{t=1, t\neq k}^{g} \underline{p}_t \leq 1, k = 1, \cdots, g.$$

Definition 15.6 Let $s_k \in S$, $\text{CCV}(s_k)$ and $m = \{(s_k, p_k)|k = 0, \cdots, g\}$ be as before, the expectation interval of m is defined as follows:

$$EI(m) = \sum_{k=0}^{g} [p_k \times \text{CCV}(s_k)], \tag{15.2}$$

where, the range of $EI(m)$ is denote as $[\underline{EI}(m), \overline{EI}(m)]$, i.e., $EI(m) \in [\underline{EI}(m), \overline{EI}(m)]$.

In the following, we develop a computational model for distribution assessments of S with interval symbolic proportion, in which there exist the following.

1. A comparison operator: Let $m_1 = \{(s_k, p_k^1)|k = 0, 1, \cdots, g\}$ and $m_2 = \{(s_k, p_k^2)|k = 0, 1, \cdots, g\}$. The expectations of m_1 and m_2 are $EI(m_1) \in [\underline{EI}(m_1), \overline{EI}(m_1)]$ and $EI(m_2) \in [\underline{EI}(m_2), \overline{EI}(m_2)]$, respectively. Then:

a. If $\underline{EI}(m_1) < \underline{EI}(m_2), \overline{EI}(m_1) < \overline{EI}(m_2)$, then $EI(m_1) < EI(m_2)$. In this case, m_1 is smaller than m_2 i.e., $m_1 < m_2$.
b. If $\underline{EI}(m_1) = \underline{EI}(m_2), \overline{EI}(m_1) = \overline{EI}(m_2)$, then $EI(m_1) = EI(m_2)$. In this case, m_1 has the same expectation interval with m_2, i.e., $m_1 = m_2$.

2. Several aggregation operators are defined as follows.

Definition 15.7 Let $\{m_1, \cdots, m_n\}$ be a set of distribution assessments of S with interval symbolic proportion, where $m_i = \{(s_k, p_k^i)|k = 0, \cdots, g\}$ and $p_k^i = [\underline{p}_k^i, \overline{p}_k^i]$, $i = 1, 2, \cdots n$. Let $\{w_1, w_2 \cdots, w_n\}$ be an associated weighting vector, such that satisfies $w_i > 0$, and $\sum_{i=1}^n w_i = 1$, where w_i is the weight of m_i. The weighted average operator of linguistic distribution assessment (denote as *IDAWA*) is defined by:

$$IDAWA\ (m_1, \cdots, m_n) = \{(s_k, p'_k)|k = 0, \cdots, g\}, \tag{15.3}$$

where $p'_k = \sum_{i=1}^n w_i p_k^i$, and $p_k^i \in [\underline{p}_k^i, \overline{p}_k^i]$.

Definition 15.8 Let $m_1, \cdots, m_n$ and $w_1, w_2 \cdots, w_n$ be as earlier. The ordered weighted average operator of linguistic distribution assessment (denote as *IDAOWA*) is defined by *IDAOWA* $(m_1, \cdots, m_n) = (s_k, p''_k)|k = 0, \cdots, g$,

$$IDAOWA(m_1, \cdots, m_n) = \{(s_k, p''_k)|k = 0, \cdots, g\}, \tag{15.4}$$

where $p''_k = \sum_{i=1}^n w_i p_k^{\sigma(i)}$, $p_k^{\sigma(i)}$ is the ith largest value in $\{p_k^1, p_k^2, \cdots p_k^n\}$, and $p_k^{\sigma(i)} \in [\underline{p}_k^{\sigma}(i), \overline{p}_k^{\sigma}(i)]$.

Several desirable properties of the *IDAOWA* operator are presented below.

Property 15.1 *Let $\{m_1, \cdots, m_n\}$ be as before. For any IDAOWA operator, IDAOWA $(m_1, \cdots, m_n)$ is a distribution assessment of S.*

Proof Based on the Definition 15.8, $IDAOWA(m_1, \cdots, m_n) = (s_k, p''_k)|k = 0, \cdots, g$ with

$$p''_k = \sum_{i=1}^{n} w_i p_k^{\sigma(i)},$$

where $m_{\sigma(i)} = \{(s_k, p_k^{\sigma(i)})\}$ is the i_th largest value in $\{m_1, \cdots, m_n\}$, and $p_k^{\sigma(i)} \in [\underline{p}_k^{\sigma(i)}, \overline{p}_k^{\sigma(i)}]$. Obviously, the range of p''_k can be denote as $[\underline{p}''_k, \overline{p}''_k]$. Then, according to the definition of the linguistic distribution assessment with interval symbolic proportion (i.e., Definition 15.5), $IDAOWA(m_1, \cdots, m_n)$ is a distribution assessment of S.

Property 15.2 *Let $\{m_1, \cdots, m_n\}$ be as before. For any IDAOWA operator* $\min_i m_i \leq IDAOWA(m_1, \cdots, m_n) \leq \max_i m_i$.

Proof Let $\{\sigma(1), \cdots, \sigma(n)\}$ be a permutation of $\{1, \cdots, n\}$ such that $m_{\sigma(i-1)} \geq m_{\sigma(i)}$ for $i = 2, \cdots, n$.

From the implementation of the *IDAOWA* operator, we have:

$$
\begin{aligned}
EI(\min_i\{m_i\}) = \min_i\{EI(m_i)\} = \min_i \left\{ \sum_{k=0}^{g}((p_k^i \times \mathrm{CCV}(s_k)) \right\} \\
\leq \sum_{k=0}^{g}((p_k^i \mathrm{CCV}(s_k)) = \sum_{k=0}^{g}\left[\sum_{i=1}^{n} w_i p_k^{\sigma(i)} \times \mathrm{CCV}(s_k)\right] \\
= EI(IDAOWA(m_1, \cdots, m_n)) \\
\leq \max_i \left\{ \sum_{=0}^{g}(p_k^i \times \mathrm{CCV}(s_k)) \right\} \\
= \max_i\{EI(m_i)\} = EI\left(\max_i\{m_i\}\right).
\end{aligned} \tag{15.5}
$$

Thus, this completes the proof of Property 15.2.

Property 15.3 *Monotonicity. Let* $\{m_1, \cdots, m_n\}$ *be a set of distribution assessments of S, Let* $\{k_1, \cdots, k_n\}$ *be another set of distribution assessments of S. If* $m_i \geq k_i$*, then* *IDAOWA* $(m_1, \cdots, m_n) \geq$ *IDAOWA* $(k_1, \cdots, k_n)$.

Proof Let $\{\sigma(1), \cdots, \sigma(n)\}$ be a permutation of $\{1, \cdots, n\}$ such that $m_{\sigma(i-1)} \geq m_{\sigma(i)}$ for $i = 2, \cdots, n$ and $\delta(1), \cdots, \delta(n)$ is a permutation of $1, \cdots, n$ such that $k_{\delta(i-1)} \geq k_{\delta(i)}$ for $i = 2, \cdots, n$.

Since $m_i \geq k_i$, we have $m_{\sigma(i)} \geq k_{\delta(i)}$. Thus,

$$
\begin{aligned}
EI\ (IDAOWA\ (m_1, \cdots, m_n)) = \sum_{i=1}^{n} w_i EI(m_{\sigma(i)}) = \sum_{i=1}^{n} w_i \sum_{k=0}^{g}(p_k^{\sigma(i)} \times \mathrm{CCV}(s_k)) \\
\geq \sum_{i=1}^{n} w_i EI(m_k(i)) = \sum_{i=1}^{n} w_i \sum_{k=0}^{g}(p_k^k(i) \times \mathrm{CCV}(s_k)) \\
= EI\ (IDAOWA(k_1, \cdots, k_n)).
\end{aligned} \tag{15.6}
$$

So, this completes the proof of Property 15.2.

15.4 Illustrative Examples

This section provides two examples to illustrate the operations in linguistic distribution assessments with interval symbolic proportion.

Example 15.1 Let $S^{\text{example1}} = s_0 =$ very poor, $s_1 =$ poor, $s_2 =$ average, $s_3 =$ good, $s_4 =$ very good denote the linguistic term set. Let m_1, m_2, m_3, m_4, m_5 represents a set of distribution assessments of S^{example1}. The CCVs and trapezoidal fuzzy

Table 15.1 The CCVs and trapezoidal fuzzy number of five labels in S^{example1}

Linguistic variable	Trapezoidal fuzzy number	CCV
s_0	T [0,0,0,0]	0
s_1	T [0,0.1,0.3,0.4]	0.2
s_2	T [0.3,0.4,0.6,0.7]	0.5
s_3	T [0.6,0.7,0.9,1]	0.8
s_4	T [1,1,1,1]	1

numbers in [0, 1] of five labels are defined in Table 15.1. m_1, m_2, m_3, m_4 and m_5 are listed in Table 15.2 (Table 15.3).

Without loss of generality, we assume that $\omega = (0.2, 0.1, 0.2, 0.3, 0.2)^T$. Then,

$$
\begin{aligned}
p_0 =\ & 0.2 \times [0.1, 0.3] + 0.1 \times 0 + 0.2 \times 0 + 0.3 \times [0.2, 0.4] + 0.2 \times 0 = [0.08, 0.18],\\
p_1 =\ & 0.2 \times [0.1, 0.3] + 0.1 \times [0.8, 1] + 0.2 \times 0 + 0.3 \times [0.2, 0.4] + 0.2 \times 0\\
=\ & [0.16, 0.28],\\
p_2 =\ & 0.2 \times [0.1, 0.3] + 0.1 \times [0, 0.2] + 0.2 \times [0.3, 0.5]\\
& + 0.3 \times [0.4, 0.6] + 0.2 \times [0, 0.2] = [0.2, 0.36],\\
p_3 =\ & 0.2 \times [0.1, 0.3] + 0.1 \times 0 + 0.2 \times [0.5, 0.7] + 0.3 \times 0 + 0.2 \times [0.7, 0.9]\\
=\ & [0.26, 0.38],\\
p_4 =\ & 0.2 \times [0.1, 0.3] + 0.1 \times 0 + 0.2 \times 0 + 0.3 \times 0 + 0.2 \times [0, 0.2] = [0.02, 0.1].
\end{aligned}
$$

So, *IDAWA* $(m_1, m_2, m_3, m_4, m_5) = \{(s_0, [0.08, 018]), (s_1, [0.16, 0.28]), (s_2, [0.2, 0.36]), (s_3, [0.26, 0.38]), (s_4, [0.02, 0.1])\}$.

When using *IDAOWA* operator, we first obtain the expectation interval values of m_1, m_2, m_3, m_4 and m_5: $EI(m_1) = [0.25, 0.75]$, $EI(m_2) = [0.16, 0.3]$, $EI(m_3) = [0.55, 0.81]$, $EI(m_4) = [0.24, 0.38]$, $EI(m_5) = [0.56, 0.94]$.

It can be got that $EI(m_5) > EI(m_3) > EI(m_1) > EI(m_4) > EI(m_2)$.

The $IDAOWA(m_1, m_2, m_3, m_4, m_5) = \{(s_k, p_k)|k = 0, \cdots, 4\}$, where

$$
\begin{aligned}
p_0 &= 0.2 \times 0 + 0.10 + 0.2 \times [0.1, 0.3] + 0.3 \times [0.2, 0.4] + 0.2 \times 0 = [0.08, 0.18],\\
p_1 &= 0.2 \times 0 + 0.1 \times 0 + 0.2 \times [0.1, 0.3] + 0.3 \times [02, 0.4] + 0.2 \times [0, 0.2]\\
&= [0.08, 0.22],\\
p_2 &= 0.2 \times [0, 0.2] + 0.1 \times [0.3, 0.5] + 0.2 \times [0.1, 0.3]\\
&\quad + 0.3 \times [0.4, 0.6] + 0.2 \times [0.8, 1] = [0.17, 0.53],\\
p_3 &= 0.2 \times [0.7, 0.9] + 0.1 \times [0.5, 0.7] + 0.2 \times [0.1, 0.3] + 0.3 \times 0 + 0.2 \times 0\\
&= [0.21, 0.31],\\
p_4 &= 0.2 \times [0, 0.2] + 0.1 \times 0 + 0.2 \times [0.1, 0.3] + 0.3 \times 0 + 0.2 \times 0 = [0.02, 0.1].
\end{aligned}
$$

So, *IDAOWA* $(m_1, m_2, m_3, m_4, m_5) = \{(s_0, [0.08, 018]), (s_1, [0.08, 0.22]), (s_2, [0.17, 0.53]), (s_3, [0.21, 0.31]), (s_4, [0.02, 0.1])\}$.

Table 15.2 The distribution assessments of S^{example1}

m_i	Distribution assessment
m_1	$\{(s_0, [0, 1, 0.3]), (s_1, [0, 1, 0.3]), (s_2, [0, 1, 0.3]), (s_3, [0, 1, 0.3]), (s_4, [0, 1, 0.3])\}$
m_2	$\{(s_0, 0), (s_1, [0.8, 1]), (s_2, [0, 0.2]), (s_3, 0), (s_4, 0)\}$
m_3	$\{(s_0, 0), (s_1, 0), (s_2, [0.3, 0.5]), (s_3, [0.5, 0.7]), (s_4, 0)\}$
m_4	$\{(s_0, [0.2, 0.4]), (s_1, [0.2, 0.4]), (s_2, [0.4, 0.6]), (s_3, 0), (s_4, 0)\}$
m_5	$\{(s_0, 0), (s_1, 0), (s_2, [0, 0.2]), (s_3, [0.7, 0.9]), (s_4, [0, 0.2])\}$

Table 15.3 The CCVs and trapezoidal fuzzy number of seven labels in S^{example2}

Linguistic variable	Trapezoidal fuzzy number	CCV
s_0	T [0,0,0,0]	0
s_1	T [0,0.05,0.15,0.2]	0.1
s_2	T [0.15,0.2,0.4,0.45]	0.3
s_3	T [0.4,0.45,0.55,0.6]	0.5
s_4	T [0.55,0.6,0.8,0.85]	0.7
s_5	T [0.8,0.85,0.95,1]	0.9
s_6	T [1,1,1,1]	1

Table 15.4 The distribution assessments of S^{example2}

m_i	Distribution assessment
m_1	$\{(s_0, [0, 0.1]), (s_1, [0.3, 0.5]), (s_2, [0.3, 0.5]), (s_3, 0), (s_4, 0), (s_5, 0), (s_6, 0)\}$
m_2	$\{(s_0, 0), (s_1, [0.2, 0.4]), (s_2, [0.4, 0.6]), (s_3, [0, 0.2]), (s_4, 0), (s_5, 0), (s_6, 0)\}$
m_3	$\{(s_0, 0), (s_1, 0), (s_2, 0), (s_3, [0.5, 0.7]), (s_4, [0.1, 0.3], (s_5, [0, 0.2]), (s_6, 0)\}$
m_4	$\{(s_0, [0.2, 0.4]), (s_1, [0.2, 0.4]), (s_2, [0.4, 0.6]), (s_3, 0), (s_4, 0)\}$

Example 15.2 Let $S^{\text{example2}} = \{s_0 = \text{extremly poor}, s_1 = \text{very poor}, s_2 = \text{poor}, s_3 = \text{average}, s_4 = \text{good}, s_5 = \text{very good}, s_6 = \text{extremly good}\}$. Let $m = \{m_1, m_2, m_3, m_4\}$ represents the set of distribution assessments of S^{example2}. The CCVs and trapezoidal fuzzy numbers in [0, 1] of seven labels are defined in Table 15.3. m_1, m_2, m_3, and m_4 are listed in Table 15.4.

Without loss of generality, we assume that $\omega = 0.2, 0.3, 0.3, 0.2)^T$. Then,

$$p_0 = 0.2 \times [0, 0.1] + 0.3 \times 0 + 0.30 + 0.20 = [0, 0.02]],$$

$$p_1 = 0.2 \times [0.3, 0.5] + 0.3 \times [0.2, 0.4] + 0.3 \times 0 + 0.2 \times 0 = [0.12, 0.22],$$

$$p_2 = 0.2 \times [0.3, 0.5] + 0.3 \times [0.4, 0.6] + 0.2 \times 0 + 0.2 \times 0 = [0.18, 0.28],$$

$$p_3 = 0.2 \times 0 + 0.3 \times [0, 0.2] + 0.3 \times [0.5, 0.7] + 0.2 \times 0 = [0.15, 0.27],$$

$$p_4 = 0.2 \times 0 + 0.3 \times 0 + 0.3 \times [0.1, 0.3] + 0.2 \times [0, 0.2] = [0.03, 0.13],$$
$$p_5 = 0.2 \times 0 + 0.3 \times 0 + 0.3 \times [0, 0.2] + 0.2 \times [0.6, 0.8] = [0.12, 0.22],$$
$$p_6 = 0.2 \times 0 + 0.3 \times 0 + 0.3 \times 0 + 0.2 \times [0, 0.2] = [0, 0.04].$$

So, $IDAWA\ (m_1, m_2, m_3, m_4, m_5) = \{(s_0, [0, 0.02]), (s_1, [0.12, 0.22]), (s_2, [0.18, 0.28]), (s_3, [0.15, 0.27]), (s_4, [0.03, 0.13]), (s_5, [0.12, 0.22]), (s_6, [0, 0.04])\}$.

Similarly, we can obtain $EI(m_1) = [0.12, 0.2]$, $EI(m_2) = [0.14, 0.32]$, $EI(m_3) = [0.32, 0.74]$, $EI(m_4) = [0.54, 1.06]$.

$$EI(m_4) > EI(m_3) > EI(m_2) > EI(m_1).$$

So, $IDAOWA(m_1, m_2, m_3, m_4) = \{(s_0, [0, 0.02]), (s_1, [0.12, 0.22]), (s_2, [0.18, 0.28]), (s_3, [0.15, 0.27]), (s_4, [0.03, 0.13]), (s_5, [0.12, 0.22]), (s_6, [0, 0.04])\}$.

15.5 Conclusions

For distribution assessments in a linguistic term set, symbolic proportions are assigned to all the linguistic terms [21]. This paper proposes a novel concept of linguistic distribution assessments and develops the corresponding computational model. The main points are as follows:

1. This paper proposes the concept of distribution assessments with interval symbolic proportion, which generalize the symbolic proportion to a more common context.
2. Several aggregation operators and computational models are presented to deal with interval symbolic proportion.

In future research, we plan to extend the interval symbolic proportion to two or more linguistic term sets with different granularities.

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Chapter 16
Interval Forecasting Model with ARIMA for Monitoring Indicators of Small and Micro Enterprises in Sichuan Province

Rui Wang, Shuang Zhao and Ting Peng

Abstract For the operational monitoring indicators and confidence indicators data of a number of small and micro enterprises in Sichuan Province in 2012 throughout the year and 2rd–4th month in 2013, and based on originally identified ARIMA time series model on the original data, we blurred into an interval according to certain rules, and then were made to the lower limit of the range using identified ARIMA time series model, to get a prediction interval. Finally, based on these results, some policy proposals on small and micro enterprises in Sichuan Province are put forward.

Keywords Small and micro enterprises · ARIMA · Range forecast

16.1 Introduction

One of the forces developed in recent years with the growing urban development process, and Sichuan Province is also expanding its business development. In addition to the introduction of large-scale enterprises development, the development of small and micro enterprises are also not to be underestimated, so the government for the development of small and micro enterprises is also very great importance, and gives a lot of support on policy and funding. Based on this, from the operation of monitoring indicators and confidence monitoring indicators collected of small and micro enterprises, we establish time series models, and give each of these indicators range forecasting and prediction interval. Predicted results for the development of small and micro enterprises in Sichuan Province has a guiding role and help the government develop and publish policies. Commonly used fuzzy prediction methods include triangular fuzzy prediction and interval prediction. The method used in this paper is combination of interval number and determined prediction. Forecast has been

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_16,

developed as a mature discipline. Both in the thinking process and methodology, there is a relatively complete system being used as support. In the projection process, selecting the prediction method is very important. According to statistics relevant information, there are more than 200 kinds of prediction methods up to now. From the classic consumption method, elastic coefficient, statistical analysis, to the gray prediction, expert system and fuzzy mathematics method in the present, even just the rise of the neural network method, the preferred combination method and wavelet analysis method. And in the past, most of the predictive models used determined prediction model to predict. So the effect of prediction may not be good when the data has a relatively large fluctuation or the amount of data is relatively small. Fuzzy prediction method can be predicted to some extent limited, relatively speaking, the result will be precise.

16.2 Interval Forecasting Model with ARIMA

16.2.1 General ARIMA Forecasting Model

Differential autoregressive moving average model (ARIMA (p, d, q)), also called autoregressive integrated moving average model, is a well-known time series prediction method proposed by Box and Jenkins in the early 1970s, so also known as the box-jenkins model, box-jenkins act. Wherein ARIMA (p, d, q) is called a differential autoregressive moving average model, AR is autoregressive, p is autoregressive term; MA is moving average, q is the number of items moving average, and d is made to be the differential times when the time series become stable.

Defined the first-order differential operator ∇ as, then the differential operator $\nabla_{Z_t} = Z_t - Z_{t-1}$ and the delay operator B has the following relationship: $\nabla = 1 - B$, $\nabla^2 = (1 - B)^2$, $\nabla^d = (1 - B)^d$, where in d is the differential of the order.

Make $\{Z_t\}$ as a non-stationary series, $\{x_t\}$ as ARIMA (p, q) sequence. There is a positive integer d, making $x_t = \nabla^d Z_t, t > d$, then: $\varphi(B)(1 - B)^d Z_t = \theta(B)d_t$.

The model is a differential autoregressive moving average model, denoted by ARIMA (p, d, q).

16.2.2 Steps of ARIMA Forecasting Model

Step 1. Data preprocessing. Preprocessing the data and collecting the basic information of data are make the basic characteristics of the data evident, and processing data so that the data can meet the requirements of the model. Data preprocessing includes data sampling, visual analysis, feature analysis, and correlation analysis. First, the definition of the data period. Selecting the monthly data or quarterly data, monthly data cycle length is 12 by default, quarterly data default cycle length is 4. Then collect the data sample. Selecting cases, then the remaining data is used to test the predictive value. Then make a sequence diagram data in SPSS, and observe the trend of sequence diagram. Then draw a histogram of the data, which shows some basic information about the variables, including the mean, variance, and sample size. Finally, correlation analysis. Drawing the image of correlation and partial correlation and analyzing correlation.

Step 2. The model identification. Observing the image of autocorrelation and partial autocorrelation function to determine the stability of the time series, and establish the appropriate model.

When $k > 3$, if the autocorrelation function of the time series falls within the confidence interval, and gradually goes to zero, then the time series have stationary and establish ARMA model; If the data sequence is non-stationary, and there is a decrease or growth in trends, we need to make a data differencing and build ARIMA model or SARIMA model; If the time series is unstable sequences, these two variables must be properly converted to make it into a stable sequence before you can be Grand Jay causality test; generally, people are concerned about the trend and seasonal or cycle components time series are not stable, then you need to make a time series differential to eliminate these ingredients that are not smooth to become stable time sequence, and estimate the ARMA model, then change the model to adapt to the process and results before the differential sequence. Stationary time series have three major forms, namely AR sequence, MA sequence, ARMA sequence; non-stationary series can use ARIMA (p, d, q) sequence to identify. $d = 0$ or 1, generally not more than two, we can get the available stable sequence ARMA (p, q), after smoothing the data, you can use ARMA model to estimate parameter method and model the paired data.

Determine the order. When analyze the correlation of time series, after determining what kind of model by the use of these basic guidelines, you need to determine the order of the model. In SPSS software, calculating correlation function and the partial correlation function, and drawing the image. We use their nature censored and tailing to determine the order. In model ARIMA (p, d, q), the value of d is generally not more than 2, and p, q cannot be directly determined. First, assuming a set of initial values, generally from the (1, 1), to a set of models. And we will find an optimal model by AIC, BIC and other criteria.

Step 3. Parameter estimation. At the same time with determining the number of models, we can test the significance by T statistic; determine the parameters and the reasonableness of the model.

Step 4. Prediction model. After obtaining the optimal parameter estimation and model structure, substituting the value, you can get the fitting data and draw a figure to fit it exactly; the predicted value can be obtained from the figure, and can get the predictive accuracy.

16.2.3 Interval Prediction Rules and Procedures

1. Interval scaling rules

Because the value of monitoring indicators generally runs relatively large, in order to ensure the zoom range will not too much, scaling formula given as follows:

- Interval estimation scaling = | Actual value − mean |/ mean * 10 %.
- Then, the estimated upper limit of the range: the actual value * (1 + scaling).
- And, the lower limit of the interval estimation: the actual value * (1 − scaling).

Because the value of the confidence index is generally between [0,100], scaling formula given as follows:

- Interval estimation scaling = | Actual value − mean |/ mean.
- Similarly, the upper limit of the range is estimated as follows: the actual value * (1 + scaling).
- And, the lower limit of the interval estimation: the actual value * (1 − scaling).

2. Cumulative value approach

If the indicators that used are cumulative value, you need a certain treatment. For our problem, we use data throughout 2012 and February 2013 to forecast data of March and April in 2013.

Therefore, the cumulative value of forecasting in March and April 2013 is calculated as follows:

- The cumulative value of March 2013 = overall cumulative value of March 2013—cumulative value of December 2012.
- The cumulative value April 2013 = overall cumulative value of April 2013—overall cumulated value of February 2013.

3. Steps of interval forecasts

Step 1. Obtain range of a certain indicator according to the above scaling rules.
Step 2. Respectively, the lower and upper limit of the range of numbers used to the Identified ARIMA forecasting model are predicted.
Step 3. If the index is confidence indicators or monitoring operation indicators for the month value, the result of step 2 is the result of the indicator; if the index is the cumulative value of monitoring operation indicators, you need to follow the cumulative value processing way as above to get the accumulated value of the month this year.

Its simplified flow chart of prediction steps are shown in Fig. 16.1.

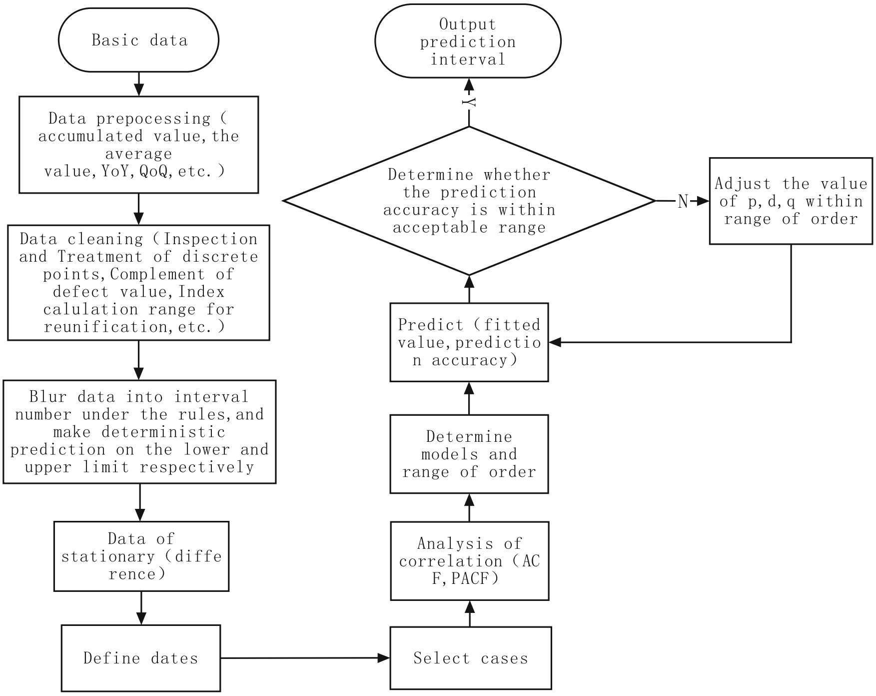

Fig. 16.1 The basic idea of interval forecasting model with ARIMA

16.3 Empirical Analyses

The data in this section comes from the monitoring operation indicators and business confidence index indicator of small and micro enterprises in Sichuan Province. Mainly using ARIMA model of time series to predict these indicators and calculate the prediction error to determine the predictive effect and make recommendations for the economic situation and government policies and analyze the reasons. This paper mainly forecasts and makes policy analysis for indicator of small and micro enterprises in Sichuan Province s. In order to be more detailed and regularly describe the nature and characteristics of these enterprises, we list the amount of the loss, the loss, operating income, operating costs, total profits and a dozen operational monitoring indicators, and a number of confidence indicators, such as the overall production and operation conditions of enterprises (this month actually), the overall production and operation conditions of enterprises (forecast next month), corporate operating conditions of the industry as a whole (this month actually), corporate operating conditions of the industry as a whole (forecast next month), implementation of the policy. Also according to the size of these companies, we divide enterprises into small, micro and small and micro in general; according to the type of industry

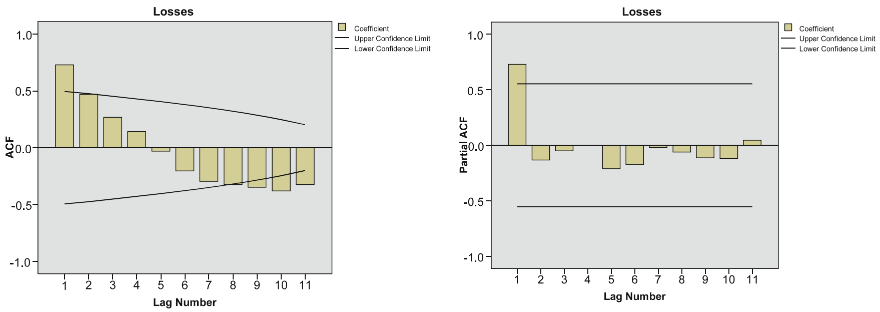

Fig. 16.2 The autocorrelation function (*left*) and partial autocorrelation function (*right*) of the lower limit losses cumulative value of the small business in Sichuan Province

we divide them into the computer, communications and other electronic equipment manufacturing, agro-food processing industry, and general equipment manufacturing industry. And finally, we predict indicators as above respectively.

16.3.1 Accumulated Value Prediction of Small Business Losses

1. Interval Scale

In accordance with the scaling rules described as above, we obtain:

The upper limit of accumulated losses value of small business = actual value $*$ $(1 + |\text{Actual value} - \text{mean}|/\text{mean} * 10\,\%)$, lower limit = actual value $*$ $(1 - |\text{actual value} - \text{mean}|/\text{mean} * 10\,\%)$.

2. Data Preprocessing

Process data with SPSS. First the data of the cumulative lower losses value of the small businesses is defined period; select the monthly data, monthly data cycle length is 12. Then data sampling, select cases, select January 2012 to January 2013 as the sample data, and the remaining data used to test the predictive value. Then we make a sequence diagram in SPSS, observe trends of sequence diagram, and find no significant change in the period and seasonal. So it's non-stationary sequence, and make a first-order differential, that is $d = 1$, to obtain a smooth sequence.

3. Pattern Recognition

Do the image of autocorrelation function and partial correlation to determine the values of p and q (Figs. 16.2 and 16.3). The figure shows that the autocorrelation coefficients and partial autocorrelation coefficients have tailing nature. When $k = 1, 2, 3, 4$, the autocorrelation coefficient is significantly different from 0, p can be 1, 2, 3, 4. When $k = 1$, the partial correlation coefficient is significantly different from 0, $q = 1$.

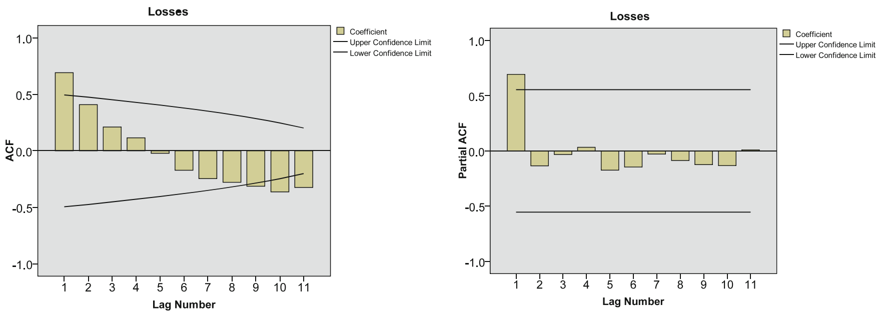

Fig. 16.3 The autocorrelation function (*left*) and partial autocorrelation function (*right*) of the upper limit losses cumulative value of the small business in Sichuan Province

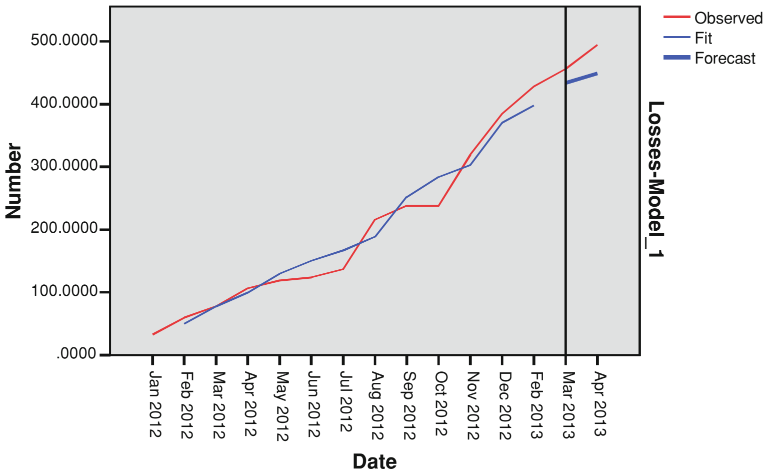

Fig. 16.4 The forecast of lower limit losses cumulative value of the small business in Sichuan Province

4. Modeling and Forecasting

By trying possible values of p, q and by BIC and parametric test, and observing the fitting effect and predicted values, we ultimately determine the model ARIMA (1, 1, 1). Its fitting results shows in Figs. 16.4 and 16.5. Fitting good results, and forecast accuracy are: lower limit of March is 0.5868 %, the lower limit is 3.730 % in April; cap is 0.5868 % in March, the upper limit is 3.730 % in April. Basically, prediction accuracy is all within 5 %, which may be considered that prediction effect is very good.

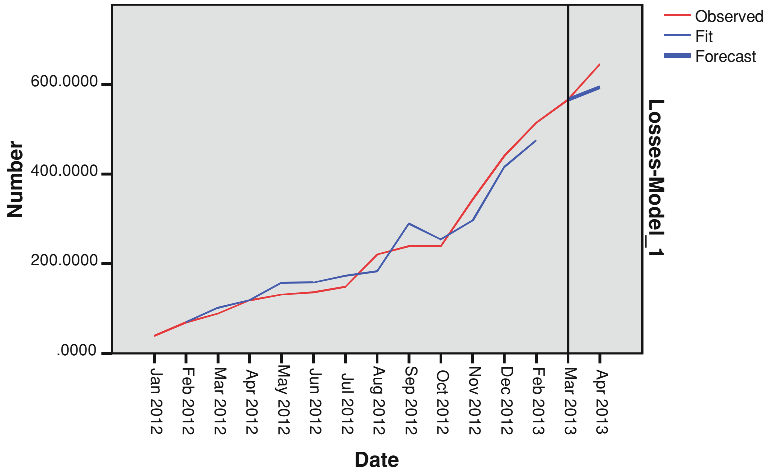

Fig. 16.5 The forecast of upper limit losses cumulative value of the small business in Sichuan Province

5. Final Results

According to the formula as above to calculate the cumulative value of this year, you can transform the overall cumulative value into the accumulated value of this year, and test the actual value whether is within the resulting range.

16.3.2 Forecast of Revenue Cumulative Value of Agro-food Processing Industry

Similar to the steps and methods as above, we can get the optimal model of upper and lower limits of agro-food processing industry; it's ARIMA (1, 1, 1). Its fitting results shows in Figs. 16.6, 16.7. Fitting results are good, and forecast accuracy is as follows: March lower limit is 0.4318 %, the lower limit of 3.8024 % in April; cap is 0.4796 % in March, the upper limit of 1.8108 % in April. Basically prediction accuracy is within 5 %, and can be considered prediction effect very good. Then again, according to the formula, calculate the cumulative value of the final prediction interval.

16.3.3 Forecast of Operating Conditions of the Industry of Small Business Enterprises as a Whole (Next Month Forecast)

There are different from processing method of confidence indicators and operation monitoring. Lower limit of enterprises operating conditions of the small business

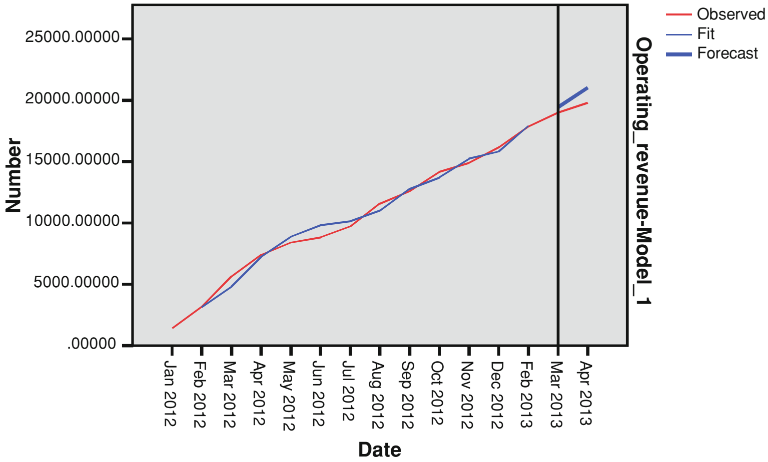

Fig. 16.6 Forecast of revenue lower limit of agro-food processing industry in Sichuan Province

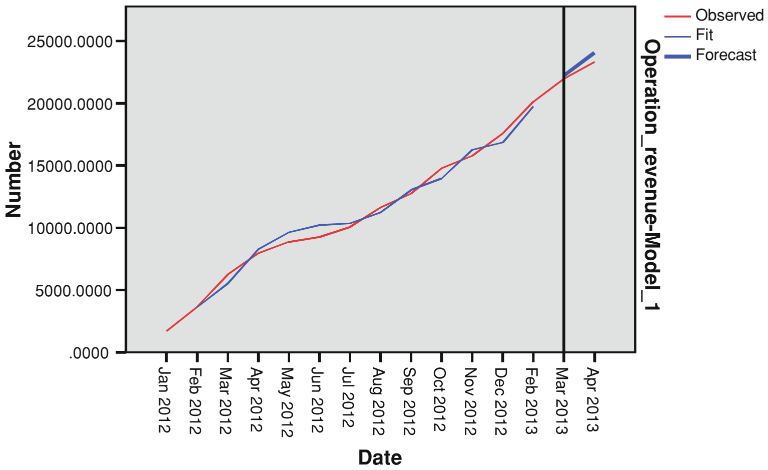

Fig. 16.7 Forecast of revenue upper limit of agro-food processing industry in Sichuan Province

sector as a whole (next month forecast) = actual value $*$ (1 $-$ |actual value $-$ mean|/mean), upper limit = actual value $*$ (1 + |Actual value $-$ mean|/mean). Other steps and methods are same with operation monitoring indicators as above. In this case, the upper and lower limits of the optimal models are both ARIMA (1, 0, 0). Its fitting results shows in Figs. 16.8, 16.9. Fitting results are good, and forecast accuracy is as follows: lower limit of March is 0.5721 %, the lower limit of 0.5953 % in April; cap is 0.1244 % in March, the upper limit is 0.8451 % in April. The basic prediction accuracy is in the range of 1 %, and it can be considered prediction effect very good. Its upper and lower limit is the final prediction interval.

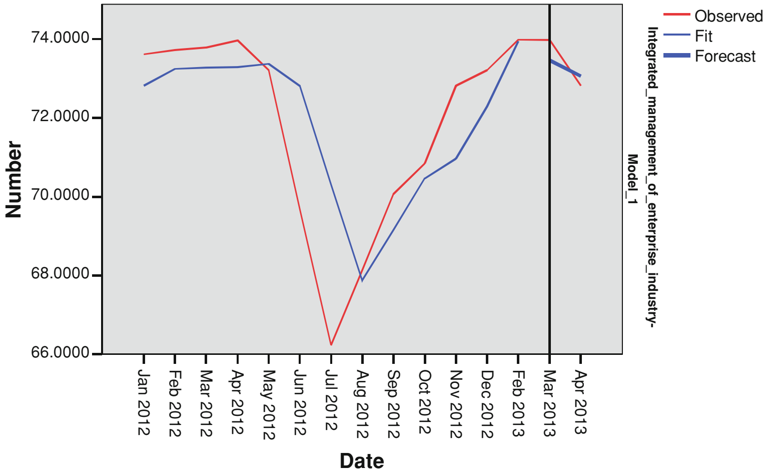

Fig. 16.8 The lower limit forecast of operating conditions of the industry of small business enterprises in Sichuan Province

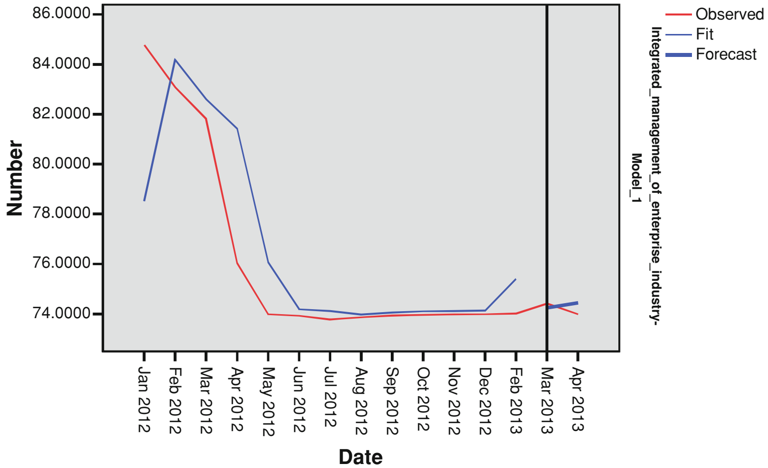

Fig. 16.9 The upper limit forecast of operating conditions of the industry of small business enterprises in Sichuan Province

16.4 Conclusions

The whole forecasting model groups are mainly for the annual number of indicators and data of small and micro enterprises in Sichuan Province in 2012 and from February to April in 2013. Divided them into two blocks: forecasts for operational monitoring indicators and forecasts for confidence index.

First for the operational monitoring indicators, the first part of the model describes forecast for the use of operational monitoring indicators of small and micro enterprises in Sichuan Province in 2012 and in February 2013 to predict the data of March and April in 2013. And according to the size of enterprises, we divide them into small businesses, micro-enterprises, small and micro enterprises. According to industry, it has the computer, communications and other electronic equipment manufacturing, agro-food processing industry, as well as general equipment manufacturing industry. And each indicator has predicted respectively.

From the predicted results, we can see just from the predictable effect that the cumulative value predicting losses, operating income, operating costs, gross profit forecast results are better, the fit is good, and the prediction error remained at less than 5 %. However, the effect of predicting scale of losses is almost opposite: on the one hand, because of value of scale of losses is only between [0, 100]; on the other hand, changes range in scale of losses are not large, and the image showing on the fitting is ineffective.

For the indicators confidence index, the second part describes the use of confidence index of small and micro enterprises in Sichuan Province in 2012 and in February 2013 to predict the data for March and April 2013. And according to the size of enterprises, we divide them into small businesses, micro-enterprises, small and micro enterprises. And we predict data on the company's overall production and operation (this month actually), the company's overall production and operation conditions (forecast next month), corporate operating conditions of the industry as a whole (this month actual), corporate operating conditions of the industry as a whole (forecast next month), as well as the implementation of supportive policies.

Overall, the indicators forecast for 2013 are maintaining about 70 points on the middle rating. The indicators that the overall production and management of small business enterprise (forecast next month), the condition that supports the implementation of the policy, the overall production operating conditions of micro-enterprises (this month actually) are expected to 75–80 points, while the rest of the indicators are in 75 points or less. Conditions of enterprises in production and operation as well as conditions of supporting the implementation of the government are in a low state, and should be improved.

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Chapter 17
Modeling Business Interoperability in a Context of Collaborative Supply Chain Networks

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Abstract This paper proposes a methodology for modeling interoperability in a context of collaborative Supply Chain Networks. The purpose of the study is to develop a methodology that enables: (1) the design of collaborative Supply Chain Network platforms that are able to deliver a high degree of business interoperability in the implementation of collaborative Supply Chain Network management practices; and (2) the analysis of the impact of business interoperability on the performance of collaborative organizations that are involved in the implementation of those management practices. The design of the Supply Chain Network platforms is grounded on the Axiomatic Design Theory and the analysis of the impact is grounded on the Agent-based Simulation. A theoretical axiomatic design model and a theoretical agent-based simulation model are proposed. The proposed methodology is demonstrated through an application scenario to implement Reverse Logistics in a context of automotive industry. The results show that this methodology is a good starting point for a more comprehensive framework towards interoperable Supply Chain Network modelling.

Keywords Business interoperability · Collaborative supply chain networks · Collaborative management practices · Axiomatic design theory · Agent-based simulation

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_17,

17.1 Introduction

There is general awareness that organizations cannot compete as isolated entities; it is obvious that working together in networks would be much easier [30] and much productive if achieved in an effective way. However, one of the main problems that organizations face when it comes to working together is the existence of business interoperability problems. Business interoperability can be defined as 'the organizational and operational ability of one business unit to collaborate or cooperate with its business partners and to efficiently establish, conduct and develop information technology (IT)-supported business relationships with the objective to create value [1]. A study conducted by Gallaher et al. [20] estimated the efficiency losses in the U.S. capital facilities industry resulting from inadequate interoperability. This study quantified U.S. $15.8 billion in annual interoperability cost, namely design changes due to inadequate information access, construction changes due to inadequate information access, manual data re-entry, paper-based information management systems, etc.

In order to overcome the managerial problems of business interoperability, a number of researchers have been attempting to establish a solution that can be used as reference. Nevertheless, a comprehensive solution to those problems, mainly in a context of Supply Chain Networks (SCNs) is still missing. For instance, Grilo et al. [21] stated that although there is considerable effort in interoperability standards development, there still exists today a failure to deliver seamless architecture, engineering and construction interoperability. Corella et al. [12] also agree that there are few real practical examples of Supply Chain (SC) interoperability that can be used as a reference. Indeed, the literature shows that most of the studies conducted up to now have focused on the study of individual dimensions of business interoperability, e.g. information systems [13, 27] or on the integration of only few dimensions, e.g. business, knowledge and information and communication technologies (ICT) dimensions [25], organizational, semantic and technical dimensions [14, 19], business, process, services and data dimensions [8], technical, syntactic, semantic, and organizational dimensions [31]. Even those researches that have explored the issue of business interoperability as a multidimensional construct [1, 32, 36] did not provide an explanation on how to simultaneously integrate the various dimensions of business interoperability nor how they relate to each other; and did not provide an explanation on how to analyze the impact of business interoperability on the performance of networked organizations (e.g. [17]). Therefore, as a new contribution to overcome the managerial problems and the research gaps addressed above, this paper grounds in a context of collaborative SCNs to propose amethodology that enables: (1) the design of collaborative SCN platforms that are able to deliver a high degree of business interoperability (DBI) in a context of collaborative SCN management practices implementation; and (2) the analysis of the impact of (low) interoperability on the performance of these collaborative SCN platforms.

The remainder of this article is structured as follows: Sect. 17.2 looks at the background on collaborative SCNs. Section 17.3 introduces the concept of business interoperability, the major existing initiatives and frameworks, and the dimensions of business interoperability. Section 17.4 presents a theoretical axiomatic design (AD) model and a theoretical agent-based simulation (ABS) model developed to guide in the modeling of collaborative SCN platforms. In the Sect. 17.5, the applicability of the proposed modelsis tested through an application scenario to implement Reverse Logistics (RL) in a context of an automotive SCN. Section 17.6 presents the potential implications for theory and practice.

17.2 Theoretical Background

In the context of business relationships, networking refers to any kind of organization structures in which two or more geographically dispersed business units need to work in interaction [34]. A business network is a set of connected actors performing different types of activities in interaction with each other [24]. In a context of SCNs, a network can be defined as a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer [29]. Chituc et al. [11] define collaborative SCNs as a collection of heterogeneous organizations with different competences, but symbiotic interests that join and efficiently combine the most suitable set of skills and resources (e.g. knowledge, capital, assets) for a time interval in order to achieve a common objective, and make use of ICTs to coordinate, develop and support their activities. In brief, the objective of a collaborative SCN is to achieve synergistic results.

17.3 Business Interoperability

Interoperability is defined as 'the ability of ICT systems and of the business processes they support to exchange data and to enable the sharing of information and knowledge' [14]. However, this definition is mainly focused on the 'technical aspects of exchanging information between ICT systems'. Interoperability should not only be considered a property of ICT systems, but should also concern to the business processes and to the business context of an organization [2]. A more comprehensive definition should be provided in order to address the other aspects of business. Thus, the concept of business interoperability is introduced. Figay et al. [18] define business interoperability as 'a field of activities with the aim to improve the manner in which organizations, by means ICTs, interoperate with other organizations, or with other business units of the same organization, in order to conduct their business'. Regarding at the major initiatives and frameworks on interoperability/business interoperability proposed in the last thirty years, the following are highlighted and categorized as follows: (1) characterization of the dimensions of (business) interoperability and their corresponding factors [1, 8, 14, 15, 25, 32, 36]; (2) process for (business) interoperability evaluation and measurement [1, 9, 10, 13, 16, 22, 26, 28, 36]; (3) development of (business) interoperability maturity model [1, 7, 13, 22, 23, 31]; and (4) quantification/analysis of the impact of (business) interoperability on the performance of networked organizations [3, 4, 20, 27]. The dimensions of business interoperability represent the different facets of interactions at which collaborating organizations can engage in [36]. In a context of collaborative business networks, business interoperability can in the first instance be described at nine dimensions [6, 36]: business strategy, management of external relationships, collaborative management process, exchange of products and services, employees and work culture, knowledge management, business semantic, information systems and network minute details. Each dimension consists of a set of factors that are responsible for the interaction between two or more collaborative business units. For instance, collaborative business process consists of clarity, visibility, alignment, coordination, synchronization, integration, flexibility, and monitoring of collaborative business process.

17.4 Proposed Modeling Approach

17.4.1 Theoretical Axiomatic Design Model

Same as any design using the AD theory, our design starts with the identification of the customer needs (CNs). Customers are the end-users of the SCN platform being modeled, that is, automaker, suppliers, distributors, retailers, logistics providers, recyclers, disposal centers, etc. In the development of the theoretical AD model we assumed that: (1) “implementation of collaborative SCN management practices” is CN; (2) “dimensions of business interoperability (and their corresponding factors)” are functional requirements (FRs); and (3) “steps needed to materialize/satisfy the FRs” are design parameters (DPs). To satisfy the CN, i.e. to implement the selected practice in a seamless way, we propose the following top-level FR: FR0: Ensure interoperability in the implementation of the selected practice. The proposed DP to materialize the FR0 is DP0: Development of collaboration mechanisms among the collaborative organizations. Then we started the decomposition of the top-level FR to incorporate the dimensions of business interoperability, which represent the fundamental requirements to implement the selected collaborative SCN management practice. The decomposition is executed from the highest level of business interoperability (business strategy) to the lowest level of business interoperability (network minute details). At each level of the decomposition, a design matrix has been generated to explore the interdependence between FRs and DPs, and to evaluate the “quality” of the design matrix (as per Axiom 1). In the end, a design matrix comprising all the levels of the decomposition has been generated. This matrix is designated as “design matrix to implement the collaborative SCN management practice”. The information content (Axiom 2) is not evaluated in this paper.

17.4.2 Theoretical Agent-Based Simulation Model

Our ABS model consists of a set of networked organizations and a set of links (relationships among the networked organizations). To develop our ABS model, we have used the last level DPs (output of the AD model) as input to evaluate the current and the required DBI in each dyadic relationship and then to analyze the impact of these last level DPs on the business interoperability performance of the collaborative RL partners. In the context of this study, we call those last level DPs as "interoperability design parameters (IDP)". Those IDPs are used in the simulation model as link variables. The DBI is evaluated according to a SCN interoperability maturity model [5] consisting of five maturity classes: class 0 (isolated), class 1 (initial), class 2 (functional), class 3 (connectable), and class 4 (interoperable). The analysis of the DBI is made in terms of (dyadic) relationships but the impact is estimated at the organizational performance. Our approach to carry out the analysis of the impact is described as follows: first, one should evaluate the current and the required DBI; based on this evaluation, a distance between these two states is calculated. Having calculated this distance, a probability of problem occurrence can be estimated, based on the achieved distance. Then, one should start to conduct the analysis of the impact using information related to the performance measures (e.g. cost of transportation of one unit from organization i to organization j, cost and time spent in reprocessing information, cost and time spent in re-planning the production, etc.) and the amount of problems occurred at a given time interval. The distance for each IDP is calculated according to the following formula: *Business interoperability distance = current degree of business interoperability − required degree of business interoperability*.

17.5 Illustrative Example

In order to demonstrate the applicability of the proposed methodology, an illustrative example is presented in this section. This illustrative example is based on an application scenario to implement RL in a context of an automotive industry. In order to ensure seamless implementation of RL, an interoperable reverse SCN platform is designed through the application of the AD theory. The effectiveness of this platform is then evaluated through the application of the ABS. The organizations included in this application scenario and the relationships among them are illustrated in Fig. 17.1. Sorting and separating of returnable items (pallets/packages, damaged items, waste or scrap) are carried out internally by each organization. The First Tier Suppliers (FTSs) are responsible for the remanufacturing of nonconforming and damaged components. The considered main RL operations are: return of nonconforming and damaged components to be re-manufactured; return of pallets and packages to be reutilized; transport of waste and scrap to recycling or disposal center.

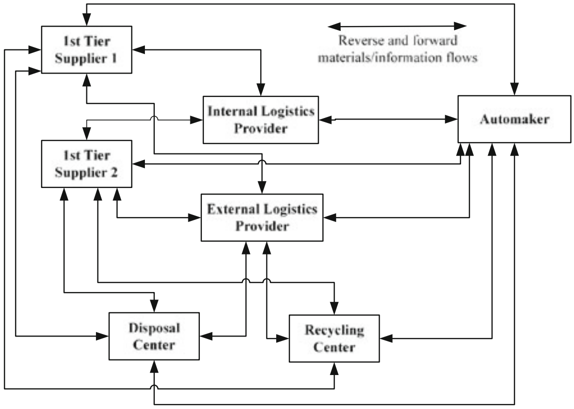

Fig. 17.1 The structure of the considered RL network

17.5.1 Demonstration of the Theoretical Axiomatic Design Model

As stated in the previous section, the purpose of the design is to develop SCN platforms that are able to ensure interoperability in the implementation of RL. Thus, the top-level functional requirement and its corresponding DP are defined as follows:

FR_0: *Ensure interoperability in the implementation of RL.*
DP_0: *Development of collaboration mechanisms among RL partners.*

As FR_0 does not provide sufficient detail to implement RL, this FR was decomposed in order to incorporate the dimensions of interoperability described in Sect. 17.3. Table 17.1 illustrates the decomposition of the level 1 FRs and their corresponding DPs. This decomposition does not include factors related to the knowledge management because it is assumed that there are no issues of intellectual property rights involved in the implementation of RL.

To evaluate the independence axiom for the level 1 FRs, a design matrix is shown in Fig. 17.2. This matrix provides the sequence of implementation of the DPs. For instance, to achieve the last functional requirement ($FR_{1.8}$), the design parameters $DP_{1.1}$, $DP_{1.2}$, $DP_{1.3}$, $DP_{1.4}$, and $DP_{1.7}$ must be implemented before of $DP_{1.8}$.

As can be observed in Fig. 17.2, the design matrix for the level 1 FRs is decoupled, as all upper triangular elements are equal to zero. Because there are some lower triangular elements that are different from zero, the independence of FRs can be guaranteed if and only if the DPs are determined in a proper sequence [33]. However, with the present decomposition the design does not get required detail because most of the proposed FRs are too much abstract. Therefore, the designer should go back to the functional domain and decompose those FRs to the next level FRs (level 2). Following, we present the decomposition for $FR_{1.3}$ of Table 17.1, which result will be used as input to the ABS model. The decomposition of the other FRs follows the

Table 17.1 Decomposition of the level 1 FRs and corresponding DPs

FR_0: Ensure interoperability in the implementation of RL	DP_0: Development of collaboration mechanisms among RL partners
$FR_{1.1}$: Establish the collaboration goals to implement RL	$DP_{1.1}$: Description of strategic goals to implement RL
$FR_{1.2}$: Manage business relationships, from RL collaboration initiation until termination	$DP_{1.2}$: Interactive management of collaboration relationships, from initiation to termination
$FR_{1.3}$: Establish collaborative business processes to support RL implementation	$DP_{1.3}$: Design of a business process model that fits the implementation of RL
$FR_{1.4}$: Manage the transactional flows among networked RL partners	$DP_{1.4}$: Description of the conditions for transactions and interaction frequency
$FR_{1.5}$: Manage human resources involved in the implementation of RL	$DP_{1.5}$: Description of the work environment that is suitable to the characteristics of each collaborating partner's employee
$FR_{1.6}$: Ensure that collaborating RL partners interpret common or shared information in a consistent way	$DP_{1.6}$: Description of the mechanisms to prevent and/or mitigate the existence of semantics problems in RL operations
$FR_{1.7}$: Establish the information systems that enable an effective management of all data/information related to RL operations	$DP_{1.7}$: Establishment of an IT solution suitable to support RL operations in the network
$FR_{1.8}$: Provide managers with a unified tool to deal with the RL network minute details	$DP_{1.8}$: A well-established framework to deal with the RL network minute details

Fig. 17.2 Design matrix for level 1 FRs

	$DP_{1.1}$	$DP_{1.2}$	$DP_{1.3}$	$DP_{1.4}$	$DP_{1.5}$	$DP_{1.6}$	$DP_{1.7}$	$DP_{1.8}$
$FR_{1.1}$	X	0	0	0	0	0	0	0
$FR_{1.2}$	X	X	0	0	0	0	0	0
$FR_{1.3}$	X	0	X	0	0	0	0	0
$FR_{1.4}$	0	0	0	X	0	0	0	0
$FR_{1.5}$	0	0	0	0	X	0	0	0
$FR_{1.6}$	0	0	0	0	0	X	0	0
$FR_{1.7}$	0	X	X	0	0	X	X	0
$FR_{1.8}$	X	X	X	X	0	0	X	X

same approach used to decompose $FR_{1.3}$, i.e. they should include their corresponding business interoperability factors.

In order to fulfill the $FR_{1.3}$, Table 17.2 presents the main sub-FRs and sub-DPs necessary to establish and manage RL collaborative processes in a context of network.

Table 17.2 Decomposition of sub-FRs (level 2) and sub-DPs for $FR_{1.3}$

$FR_{1.3}$: Establish collaborative business processes to support RL implementation	$DP_{1.3}$: Design of a business process model that fits the implementation of RL
$FR_{2.3.1}$: Establish clear RL collaborative processes in the network	$DP_{2.3.1}$: Mechanisms to ensure clarity on the definition of entities in charge of each RL collaborative process
$FR_{2.3.2}$: Coordinate the RL collaborative processes with cooperating partners	$DP_{2.3.2}$: Establishment of the mechanisms to coordinate and synchronize RL collaborative processes along the network
$FR_{2.3.3}$: Provide visibility of the processing status of the RL collaborative processes throughout the network	$DP_{2.3.3}$: Mechanisms to communicate the processing status of the RL collaborative processes along the network
$FR_{2.3.4}$: Integrate the RL collaborative process	$DP_{2.3.4}$: Description of how to integrate the RL collaborative processes, functions and teams
$FR_{2.3.5}$: Ensure a required level of flexibility of the RL cross-organizational processes	$DP_{2.3.5}$: Description of how to adjust and reconfigure the RL collaborative processes
$FR_{2.3.6}$: Align the RL collaborative processes	$DP_{2.3.6}$: Description of the mechanism to align the RL collaborative processes
$FR_{2.3.7}$: Synchronize the RL collaborative processes with consumer demands (forward flows)	$DP_{2.3.7}$: Establishment of the mechanisms to synchronize the RL collaborative processes with forward flows
$FR_{2.3.8}$: Monitor the performance of RL collaborative processes	$DP_{2.3.8}$: Definition of the RL performance indicators and the procedures to monitor the RL collaborative processes

17.5.2 Demonstration of the Theoretical Agent-Based Simulation Model

To demonstrate the application of the theoretical ABS model, we developed an application scenario through a simulation environment developed through the Netlogo software [35]. We used three IDPs derived from the theoretical AD model: '$DP_{2.3.1}$: mechanisms to ensure clarity on the definition of entities in charge of each RL collaborative process' and '$DP_{2.3.3}$: mechanisms to communicate the processing status of the RL collaborative processes along the network'. The $DP_{2.3.3}$ is further decomposed into $DP_{3.2.3.1}$: mechanisms to communicate the processing status of the components being remanufactured and $DP_{3.2.3.2}$: mechanisms to provide visibility of the inventory level of the returnable products/materials.

The considered RL network in the demonstration of the theoretical ABS model is the same that was considered in the demonstration of the theoretical AD model. In order to conduct the analysis of the impact, we made some assumptions as the empirical data are not available at this moment: the FTS 1 delivers to the Automaker 600 type A components per day, and five times a day; the lead time for remanufactured

Table 17.3 Evolution of the average DBI

Interoperability design parameter	$t = [0, 90]$		$t = [90, 179]$		$t = [179, 266]$	
	Current	Required	Current	Required	Current	Required
$DP_{2.3.1}$	DBI $\sim N$ (1.5; 0.5)	DBI $\sim N$ (3; 0)	DBI $\sim N$ (2.5; 0.5)	DBI $\sim N$ (4; 0)	DBI $\sim N$ (3; 0.15)	DBI $\sim N$ (4; 0)
$DP_{3.2.3.1}$	DBI $\sim N$ (1; 0.3)	DBI $\sim N$ (3; 0)	DBI $\sim N$ (2; 0.4)	DBI $\sim N$ (4; 0)	DBI $\sim N$ (3; 0.3)	DBI $\sim N$ (4; 0)
$DP_{3.2.3.2}$	DBI $\sim N$ (1; 0.5)	DBI $\sim N$ (3; 0)	DBI $\sim N$ (2; 0.6)	DBI $\sim N$ (4; 0)	DBI $\sim N$ (3; 0.2)	DBI $\sim N$ (4; 0)

type type A component is 1 h; the FTS 2 delivers to the Automaker 1200 type B components per day, and five times a day; the lead time for remanufactured type A component is fourth five minutes; the transportation of these components from the FTSs to the Automaker is carried out by the Internal Logistics Provider (ILP). In each shipment of type A components, four pallets are used and each type A component is packaged using one packing; for the type B component, six pallets are used and each component is also packaged using one packing; both pallets and packings used to ship components from the FTSs to the Automaker are reusable; the organizations operate 8 h a day and five days a week; DBI for the IDPs are normally distributed, i.e. DBI $\sim N(\mu, \sigma^2)$; Table 17.3 shows how the average DBI of the links change over time.

We also assumed that: the DBI of the 'mechanisms to ensure clarity on the definition of entities in charge of each RL collaborative process' have an impact on the return rate of pallets and packing; it is assumed that the return rate of pallet/packings is between 95 and 100 % if the distance is zero, between 85 and 94 % if the distance is -1, between 65 and 84 % if the distance is -2, between 38 and 64 % if the distance is -3, and between 0 and 37 % if the distance is -4; it was assumed that for each non-returned pallet and packing, there is an impact on the inventory cost at Automaker and on the cost of acquiring new pallets and/or packing at the FTSs; it was assumed that the unit inventory cost at the Automaker is 4€ for non-returned pallets and 2€ for non-returned packings; at the FTSs, it was assumed that the cost of acquiring a new pallet is 10€ for both FTSs; the cost of acquiring a new packing is 5€ for the FTS 1 and 4€ for the FTS 2; regarding at the 'mechanisms to communicate the processing status of the components being remanufactured' we assume that its impact is on the cost and time spent in production planning at the Automaker; it was assumed that the impact (both on time and cost) is zero if the distance is zero, between 0.05 and 0.12 if the distance is -1, between 0.13 and 0.30 if the distance is -2, between 0.31 and 0.60 if the distance is -3, between 0.61 and 1 if the distance is -4; for the 'mechanisms to provide visibility of the inventory level of the returnable products/materials', it is assumed that its impact is on the cost and time spent in production planning at the organization that will receive the returned products/materials; to analyze the impact of this IDP, we considered the links from

Table 17.4 Average value for the performance measures

Performance measures (average)	Automaker		FTS 1		FTS 2		Recycling center	
	Total	Mean	Total	Mean	Total	Mean	Total	Mean
Number of returned pallets from the Automaker to the FTSs	–	–	3,907	14.74	5,854	22.09	–	–
Number of non-returned pallets from the Automaker to the FTSs	–	–	1,388	5,24	2048	7,73	–	–
Number of returned packings from the Automaker to the FTSs	–	–	120,246	452.49	23963	90.09	–	–
Number of non-returned packings from the Automaker to the FTSs			39,146	147.72	7826	29.53	–	–
Number of non-returned pallets at the Automaker	3,439	13.1	–	–	–	–	–	–
Number of non-returned packings at the Automaker	45,659	174.72	–	–	–	–	–	–
Total cost of acquiring new pallets at the FTSs (€)	–	–	13,880	52.37	20,480	77.28	–	–
Total cost of acquiring new packings at the FTSs (€)	–	–	195,730	738.6	31,304	118.12	–	–
Total inventory cost of non-returned pallets at the Automaker (€)	13,756	51.91	–	–	–	–	–	–
Total inventory cost of non-returned packings at the Automaker (€)	91,318	344.6	–	–	–	–	–	–
Total impact on the cost of production planning (€)	227,622.55	858.95	152,815.2	576.66	45,376.29	171.23	117,117.37	441.95
Total impact on the time spent in production planning (hour)	223.99	0.85	190.74	0.72	117.69	0.44	194.4	0.73

the Automaker to the FTSs and the links from the Automaker and from the FTSs to the Recycling Center; it was assumed that the impact (both on time and cost) at the FTSs is zero if the distance is zero, between 0.12 and 0.18 if the distance is −1, between 0.19 and 0.32 if the distance is −2, between 0.33 and 0.58 if the distance is −3, and between 0.59 and 1 if the distance is −4; in terms of the impact on the Recycling Center, is was assumed that the impact is zero if the distance is zero, between 0.05 and 0.15 if the distance is −1, between 0.16 and 0.30 if the distance is −2, between 0.31 and 0.6 if the distance is −3, and between 0.61 and 1 if the distance is −4; the time spent in production planning in each organization is also assumed to be normally distributed as follows: the average time spent at the Recycling Center is 2.5 h a day with a standard deviation of 15 min (0.25 h); the cost of each hour spent in production planning is assumed to be fixed in 600€; at the FTSs, the time spent in planning remanufacturing process is normally distributed with a mean of 2 h and a standard deviation of 15 min (0.25 h) and the cost of each hour spent in planning is fixed in 800€; At the Automaker the time spent in production planning is normally distributed with a mean of 4 h and a standard deviation of 30 min (0.5 h) and that the cost of each hour spent in planning is 1,000€.

17.5.3 Computational Experiments and Simulation Outputs

As the purpose of this paper is to explore and demonstrate the applicability of the proposed methodology through an application scenario, rather than to achieve generalization about the outputs obtained, the issues such as the number of replications, warm-up period as well as the confidence interval for the mean of the performance measures are not considered. The run-length of the simulation is defined to be one year. We assume that there are six holidays during the year. In each quarter it will be discounted two holidays. Therefore, the simulation runs 265 (271–276) time periods (days) of 8 h. In this paper the simulation run is executed only one time due to the reason pointed out above. The average values for each considered performance measure are summarized in Table 17.4.

17.6 Conclusions

The purpose of this paper was to add to the knowledge on operations management research by developing a methodology for modelling business interoperability in a context of collaborative SCNs. By presenting a holistic methodology that enables to integrate the various dimensions of business interoperability, this study represents a novelty on how to relate different dimensions of business interoperability (and their corresponding factors) and how to analyze their impact on the performance of networked organizations.

The preliminary findings of this research suggests important implications for the managers in the collaborative SCNs to understand how to design interoperable SCN platforms and how to analyze the impact of low interoperable platforms in the performance of networked organizations. More importantly, the proposed methodology provides decision makers with the ability to evaluate the current DBI and the points where improvement can be achieved. The preliminary findings also suggest that the combination of the AD theory with the ABS proved to be a suited tool for modeling business interoperability in a context of collaborative SCN.

Acknowledgments This research was supported by Fundação para a Ciência e aTecnologia (Project PTDC/EME-GIN/115617/2009).

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Part II
Decision Support Systems

Chapter 18
Mathematical Models of Moving Particles and Their Application for Traffic

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Abstract The mathematical models of moving particles, describing behavior of traffic systems are constructed. It is shown that Belyaev's effect about random binomial walk separately considered particle is true for more general cases. Using this fact a reason of appearance a traffic jam is shown. The class of probability distributions between moving particles is found. It is shown that any discrete probability distribution can be approximated by distribution between moving particles. Numerical examples and graphs, demonstrating these theoretical results are given.

Keywords Mathematical model · Probability distribution · Traffic systems

18.1 Introduction

Mathematical models of moving particles describe a behavior of wide class of queues. Traffic systems, transportation of goods, freight, shipping and others technical systems can be described by the mathematical models of moving particles, where particle means transport unit (car, bus, train, ship). Although, partially such systems can be formulated in the frame of standard queuing theory, but for their detailed research it is necessary to create and use the new approaches and methods from various field of mathematics.

A particular interest in this division is in mathematical models of moving particles, which describe a behavior of a wide class of complicated queuing systems and could be successfully applied for transport systems, networks of computers, biological and other systems. Collection of empirical data plays an important role for investigation

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_18,

of such systems. For instance, empirical data related to the tunnel under the Hudson Bay (USA) [3] showed that companies loose large amounts of money when delivering freights, cargo and other irregular materials due to disturbing factors such as traffic jams, long queues and others.

In 1969 Belyaev [2] constructed a simplified mathematical model on a line, of two moving particles without overtaking, where an effect of a random binomial walk of separately considered particle was proved and probability distribution between moving particles was found. This model describes a behavior of transport unit on a one-line road without overtaking. As an image of this model can be considered tunnels, where is one-line road without overtaking. This fact allowed to find out a functional dependence between intensity and density of traffic flow, which is called the road diagram. Usage of a road diagram allows to describe an appearance of a traffic jam and the attainment of a maximal value of critical intensity, when density takes minimal value. In [7], U. Zahle considered generalized Belyaev's model with mutual interaction of particles and he proved a random binomial walk of separately considered particle for this model. These approaches and models have been used [1] in the formation of the traffic system in Moscow circular road. Later on, these results have been generalized for motion on a circle [4, 5].

18.2 Mathematical Models

Consider a motion of particles on a lattice with points $x = kd, k = 0, + - 1, 2, \cdots;$ where $d > 0$ is a constant. At any time $t \in T = \{0, h, 2h, \cdots\}, h > 0$ each point of lattice can be occupied only by one particle. The particles can't come near each other to the distance not less than 1. Let us numerate particles. If at the point $x = 0$ there is particle, then we give to this particle number 0. If there is no particle at the point $x = 0$, then to the first particle from the left of the position $x = 0$ will be given number 0. To the next particle from the left will be given number -1. To the first particle right from $x = 0$ will be given number 1, to the second number 2 and so on. Introduce the function $\varepsilon_t(x)$, (which is equal 1, if at the instant t there is a particle at the point x and takes value 0, if there is no particle at the point x.

Denote $\xi_{i,t}$ the coordinates of i-th particle at the instant t, where i is an order number of particle on the lattice at the epoch t. The system can change its states at the instants $\{t = 0, h, 2h, \cdots, h > 0\}$. It is supposed that particles move only in one direction, from left to right. During a movement neighbor right particle has priority relatively to the left particle, i.e. if right particle during the time interval $(t, t + h)$ stays at the same place and distance between them equals 1, then at the instant $t + h$ the left particle must stay at the own place, i.e. the left particle must keep distance 1 relatively to the right particle.

If $\xi_{i+1,t+h} - \xi_{i,t} > d$, then i-th particle makes a random binomial walk, i.e. $P\{\xi_{i,t+h} = \xi_{i,t} + d\} = r^*$, $P\{\xi_{i,t+h} = \xi_{i,t}\} = l^*, r^* + l^* = 1$.

If $r^* > l^*$ (we assume it below) then at a free motion zone particles have tendency to move to right and an average speed of motion equals $V_{aver} = (r^* - l^*)d/h$.

The path which particle has gone for long time $t = kh$ has mean value $V_{aver} = t(r^* - l^*)d/h$ and variance $2t(r^* - l^*)d/h$. Right particles break a motion of left particles in free motion, so an average speed becomes less than V_{aver}. In such model (introduced in [7]) the following groups of particles are observing. We will say that a group of particles is observing (we call Γ_i-group) if $\xi_{i+l,t} = \xi_{i+l-1,t} + \tau$ $(l = \overline{1, k-1})$, $k = 2, 3, \cdots$; $\xi_{i-l,t} < \xi_{i,t} - \tau$, $\xi_{i+k-l,t} < \xi_{i+h,l} - \tau$ where k –is the size of group and $(i + k - 1)$-th particle is a leader of the group τ_i.

18.3 Model with Two Particles

Consider motion of two particles on a straight line. Particles are numerated from left to right and can move only in one direction (to right). Denote $\rho_{1,t} = \xi_{2,t} - \xi_{1,t}$ a distance between moving particles at the instant t and $\varepsilon_{i,t} = \xi_{i,t+h} - \xi_{i,t}$, $i = 1, 2$. For simplifying notations we will consider special case of Belyaev model, where $d = 1$, $h = 1$ and each particle at the instant t can make a jump to the right for distance 1 or to stay at the same place. One particle (right) will be called leader (its motion independent of other particle), but motion of other particle depends on behavior of leader, i.e.

$$
\begin{aligned}
&P\{\varepsilon_{2,t} = 1\} = r^*, \quad P\{\varepsilon_{2,t} = 0\} = l^*,\\
&P\{\varepsilon_{1,t} = 1/\rho_{1,t} = k\} = r, \quad P\{\varepsilon_{1,t} = 0/\rho_{1,t} = k\} = l, \quad k = 2, 3, \cdots,\\
&P\{\varepsilon_{1,t} = 1/\rho_{1,t} = 1, \varepsilon_{2,t} = 1\} = r, \quad P\{\varepsilon_{1,t} = 1/\rho_{1,t} = 1, \varepsilon_{2,t} = 0\} = 0,\\
&P\{\varepsilon_{1,t} = 0/\rho_{1,t} = 1, \varepsilon_{2,t} = 1\} = l, \quad P\{\varepsilon_{1,t} = 0/\rho_{1,t} = 1, \varepsilon_{2,t} = 1\} = 0.
\end{aligned}
$$

These formulas means that if distance $\rho_{1,t}$ between first and second particles is greater than 1, then first particle also makes random binomial walk with parameters r, l. The main assumption is $r^* < r$. If we assume also $r^* < l^*$, $r < l$, then $r^* < r$ means, that the right particle from time to time breaks down motion of the left (see, Fig. 18.1).

The left particle reaches the right particle and during of some random time they are moving in synch, having distance $d = 1$ between them. After sometime the left particle lags from right particle. Becoming free, it moves faster and again reaches the right particle and so on. We will show that for $t \to \infty$ separately considered (left) particle also makes a random walk with parameters r^*, l^*. This result can be also explained as the following: if left particle is visible and right particle is non-visible, then left particle also makes a random walk with the same parameters. From construction of the model it follows that ρ_t is homogenous Markov chain with probabilities:

$$
\begin{aligned}
&P\{\rho_{t+1} = 1/\rho_t = 1\} = 1 - lr^*, \quad P\{\rho_t = k + 2/\rho_t = k\} = lr^* > 0,\\
&P\{\rho_{t+1} = k - 2/\rho_t = k = lr^* P\{\rho_{t+1} = k/\rho_t = k\} = rr^* + ll^* > 0, (k = 1, 2, \cdots).
\end{aligned}
$$

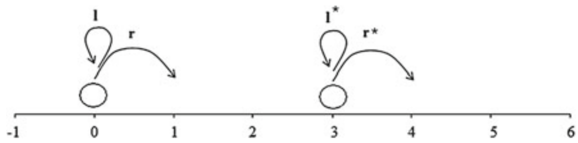

Fig. 18.1 The motion of the particles

Below there are giving some results from [2].

Theorem 18.1 *If $r^* < r$, then there exists a single stationary distribution of for which*

$$\lim_{t\to\infty} P\{\rho_{t+1} = k\} = [(rl^* - r^*l)/rl^*](lr^*/rl^*)^k,\ k = (0, 1, 2, \cdots). \tag{18.1}$$

Denote $v = r^*l/rl^*$ then it follows from Eq. (18.1) that

$$\lim_{t\to\infty} P\{\rho_t = k\} = (1-v)v^k, k = (0, 1, \cdots). \tag{18.2}$$

Assume that at the instant t distribution of ρ_t is defined by Eq. (18.1). Let us put $\varepsilon_t = 1$, if left (right) particle makes a jump and $\varepsilon_t = 0$ if left (right) particle stay at the same place and denote:

$$b(\varepsilon_t, \cdots, \varepsilon_{t+m}) = (\bar{r})^{m+}(\bar{l})^{m-}, \tag{18.3}$$

where $m^-(m^+)$—number of such $s \in \overline{t, t+m}$, for which $\varepsilon_s = 0(1)$. Our main aim is to show that Eq. (18.3) is true for any m.

Theorem 18.2 *In stationary regime we have: $b(\varepsilon_t, \cdots, \varepsilon_{t+m}, \rho_{t+m+1} = k\} = b(\varepsilon_t, \cdots, \varepsilon_{t+m})P\{\rho_{t+m+1} = k\}$.*

18.4 Stable Regime of Motion

Assume that at the initial instant $t = 0$ a distance between particles with numbers $i, i+1$—mutually independent random variables $\rho_{i,t} = \xi_{i+1,t} - \xi_{i,t}$, $t = 0$, $i = 0, \pm 1, \pm 2, \cdots$ and probabilities are defined by Eq. (18.1). It is clear that these probabilities are not changed for t, because we have stationary regime. In fact, for $r^* < r$ random variable $\rho_{i,i+1}$ has the same distribution as $\rho_{i,i}$, and $\rho_{i,t}$ independent of $\rho_{j,t}$, $j < t$. It follows from Eq. (18.2) that a number of the points in group has geometric distribution with mean value v^{-1}, and an average number of occupied lattice points by group equals τ/dv. From Eq. (18.2) follows also that an average number of lattice points, where particles have free motion of group leader is $2/(1-v)$. Thus, a probability that at the point of lattice there is particle equals:

$$\bar{\mu} = \frac{1}{v}\left(\frac{\tau}{vd} + \frac{2}{1-v}\right)^{-1} = \frac{(1-v)d}{\tau(1-v)+2vd}. \tag{18.4}$$

Density of the system, i.e. an average number of particles at the unit length (a road loading) is:

$$\bar{N} = \frac{\bar{\mu}}{d} = \frac{(1-v)d}{\tau(1-v)+2vd} \leq \frac{1}{\tau}. \tag{18.5}$$

Having value of $\overline{N}$ and also parameters of free motion l, r we can calculate r^*, l^* in stable regime. An average speed of system motion equals:

$$\bar{v} = (\bar{r} - \bar{l})d/h = \frac{r - l(1+\alpha)}{r + l(1+\alpha)} \cdot \frac{d}{h},\ \alpha = \frac{2\bar{N}d}{1-\bar{N}\tau}. \tag{18.6}$$

Let us fixed on a line the point $x \neq kd$, where k—a whole number. An average number of such particles equals:

$$\lambda = (\bar{r} - \bar{l})\bar{\mu}/h = \bar{v}\bar{N}, \tag{18.7}$$

and λ can be considered as output capacity of a road. For $r = 1, l = 0$ output capacity reaches its maximal value $\lambda_{\max} = d/h\tau$, maximal road loading $\overline{N}_{\max} = 1/\tau$ and maximal speed of particles $V_{\max} = d/h$. An average speed of particles at the free zone equals. As $V_{aver}/V_{\max} = 2r - l$, in the capacity of main parameters of the system can be considered $\overline{N}$ and $\gamma = V_{aver}/V_{\max}$. For this we take $r = \frac{1}{2}(1+\gamma)$, $l = \frac{1}{2}(1-\gamma)$.

From Eqs. (18.6) and (18.7) we find:

$$\frac{\bar{v}}{v_{\max}} = \frac{(1+r)-(1-r)(1+\alpha)}{(1+r)+(1-r)(1+\alpha)},\ \frac{\lambda}{\lambda_{\max}} = \frac{\bar{v}}{v_{\max}} \cdot \frac{\bar{S}}{S_{\max}}. \tag{18.8}$$

If road loading $\overline{N}$ increasing, then an average speed of motion $\bar{v}$ is decreasing, and $\overline{N} = \overline{N}_{crit}, \bar{v} = 0$. From Eq. (18.8) we have:

$$\bar{N}_{crei} = \frac{\gamma}{\gamma(\tau - d) + d}. \tag{18.9}$$

Thus, for $\overline{N} = \overline{N}_{crit}$ we have traffic jam and operation of the system is stopped. Simple calculations yield (see Table 18.1) that road output capacity λ as a function of $\overline{N}$ for $\gamma = \text{const}$, $0 < \gamma < 1$ attains its maximal value λ_{opt} for $\overline{N} = \overline{N}_{opt}$. In the table are given the values $\overline{N}_{opt}/\overline{N}_{\max}$ and $\lambda_{opt}/\lambda_{\max}$, when $\gamma = 0.90(0.01)0.99$ and $\tau/d = 1, 5, 15$,

Table 18.1 Simple calculations

λ		0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99
$\frac{\tau}{d} = 1$	$\frac{\bar{N}_{opt.}}{\bar{N}_{\max}}$	0.63	0.64	0.66	0.63	0.70	0.72	0.75	0.78	0.82	0.87
	$\frac{\bar{\lambda}_{opt.}}{\bar{\lambda}_{\max}}$	0.39	0.41	0.44	0.46	0.49	0.52	0.56	0.61	0.67	0.75
$\frac{\tau}{d} = 5$	$\frac{\bar{N}_{opt.}}{\bar{N}_{\max}}$	0.81	0.82	0.83	0.84	0.85	0.87	0.88	0.90	0.91	0.94
	$\frac{\bar{\lambda}_{opt.}}{\bar{\lambda}_{\max}}$	0.61	0.63	0.65	0.67	0.69	0.72	0.75	0.78	0.82	0.87
$\frac{\tau}{d} = 15$	$\frac{\bar{N}_{opt.}}{\bar{N}_{\max}}$	0.89	0.89	0.90	0.91	0.91	0.92	0.93	0.91	0.95	0.96
	$\frac{\bar{\lambda}_{opt.}}{\bar{\lambda}_{\max}}$	0.71	0.73	0.73	0.77	0.79	0.81	0.83	0.86	0.88	0.92

$$\bar{N}_{opt.}/\bar{N}_{\max} = \frac{\tau}{\tau - d(1-\gamma)}\left\{1 - \sqrt{\frac{d(1-r^2)}{[\tau\gamma + d(1-\gamma)]}}\right\}.$$

If γ closed to 1, then a motion in stable regime has speed $v_{\max}$ and from time to time (for $\overline{N} < \overline{N}_{opt}$) delay occurs, either due to the influence on the particle itself or due to delay the next right particle. The number of delayed particles is increasing with increasing a number of particles $\overline{N}$ to the critical number $\overline{N}_{crit}$.

18.5 Generalized Model of Moving Particles

Consider a motion (in one direction, from left to right) of countable number of particles on a line. Denote $\xi_{i,t}$ coordinates of i-th particle ($i = 0, \pm 1, \pm 2, \cdots$) at the instant t., τ, d, h— some fixed numbers and $T = \{0, h, 2h, \cdots\}$; $\rho_{i,t} = \xi_{i+1,t} - \xi_{i,1}$; $\varepsilon_{i,t} = \xi_{i,t+h} - \xi_{i,t}$. Particles can change their positions at the instant $t \in T = \{0, h, 2h, \cdots\}$; We will assume that at the initial instant $t = 0$ we have $\rho_{i,0} = \tau + kd$ where $k = k(i) = 0, 1, 2, \cdots$;

Particles move according to the following rules

$$P\{\varepsilon_{i,t} = d|\rho_{i,t} = kd + \tau\} = r_k, \quad k = 1, 2, \cdots,$$
$$P\{\varepsilon_{i,t} = d|\rho_{i,t} = \tau, \varepsilon_{i+1,t} = d\} = r_0; \; P\{\varepsilon_{i,t} = d|\rho_{i,t} = \tau, \varepsilon_{i+1,t} = 0\} = 0,$$
$$P\{\varepsilon_{i,t} = 0|\rho_{i,t} = kd + \tau\} = l_k, \quad k = 1, 2, \cdots; \; P\{\varepsilon_{i,t} = 0|\rho_{i,t} = \tau; \varepsilon_{i+1,t} = d\} = l_0,$$
$$P\{\varepsilon_{i,t} = 0|\rho_{i,t} = \tau; \varepsilon_{i,t} = 0\} = 1,$$

where $r_k + l_k = 1, k = 1, 2, \cdots$ see Fig. 18.2.

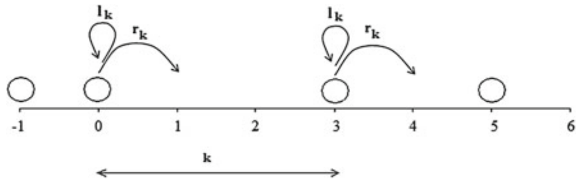

Fig. 18.2 Motion of the particles

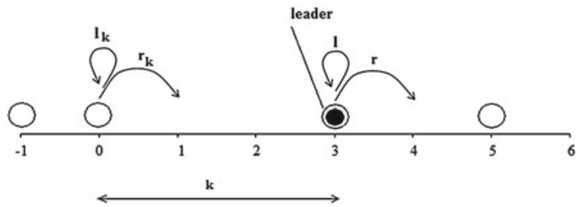

Fig. 18.3 Motion of other particle depends on a distance to the leader particle

Other words: (1) For all particles $\rho_{i,t} = kd + \tau, t \in T$; (2) Speed of each particle depends on a distance to the next particles (in the direction of motion).

We will call $\{i, i+1, \cdots, i+m;\ t\}$, $m = 0, 1, 2, \cdots$, $t \in T$ as a group of particle if $\rho_{i-1,t} > \tau$, $\rho_{i,t} = \cdots = \rho_{i+m-1,t} = \tau$ Then behavior of j-th particle at the instant t (where $\{i, \cdots, j, \cdots, i+m;\ t\}$ is a group) depends on behavior of the particles $j+1, \cdots, i+m$ and $\rho_{i+m,t}$. Below this fact will be used for proving of some facts. This model was introduced by Zahle [7].

18.5.1 Motion of Two Particles

Consider a motion of two particles. First particle (is called leader) makes a random walk according to the following rules $P\{\varepsilon_{2,t} = d\} = r < 1$, $P\{\varepsilon_{2,t} = 0\} = l$, $r + l = 1$.

Motion of other particle depends on a distance to the leader particle $P\{\varepsilon_{1,t} = d\} = r < 1$, $P\{\varepsilon_{1,t} = 0\} = l$, $r + l = 1$ (see Fig. 18.3).

We are interested in the distribution of $\rho_{1,t}$, which is independent of t. From a construction of the model follows the following equations:

$$\rho_0 = \rho_0(rr_0 + l) + \rho_1 l r_1,$$

$$\rho_k = \rho_{k-1} r l_{k-1} + \rho_k(rr_k + ll_k) + \rho_{k+1} l r_{k+1}, k = 1, 2, \cdots; \sum_{k=0}^{\infty} \rho_k = 1. \quad (18.10)$$

If $r_j > 0$ for $j = 1, 2, \cdots$ and $\sum_{k=0}^{\infty} A_k < \infty$, where $A_0 = 1$, $A_j = (r/l)\frac{l_{j-1}, \cdots, l_0}{r_j, \cdots, r_1}$, then

$$\rho_k = A_k \Big/ \sum_{j=0}^{\infty} A_j = A_k/A, k = 1, 2, \cdots, \quad (18.11)$$

is a unique solution of Eq. (18.10). The condition $\sum_{k=0}^{\infty} A_k < \infty$ means that a stationary distribution is not degenerate in $P\{\rho_{.,t} < N\} = 0 \; \forall \; N \in (0, \infty)$, and from $r_j > 0$, $j = 1, 2, \cdots$ it follows that $\rho_0 > 0$.

Which types of distributions can be presented in the form Eq. (18.11)?

18.6 Class of Probability Distributions Between Moving Particles

Consider probability distribution of ρ_t, which is defined by Eq. (18.11) and denote $B_r^{r^*}$ = {class of all probability distributions from Eq. (18.11), $r^* = (r_1, r_2, \cdots, r_n, \cdots)\}$, $B_r = \bigcup_{r^*} B_r^{r^*}$, where $r^* = (r_1, r_2, \cdots, r_n, \cdots)$, $B = \bigcup_r B_r$. It is clear that $B_r^{r^*} \subseteq B_r \subseteq B$. For any two discrete probability distributions $P = \{p_k, k = 1, 2, \cdots, \}$ and $Q = \{q_k, k = 1, 2, \cdots, \}$ according to [6] define variation distance between these distributions as $\rho(P, Q) = \sum_{i=1}^{\infty} /p_i - q_i/$. Which type of discrete probability distributions can be represented in the form (4.4), i.e. is it possible to approximate any discrete probability distribution by the distributions from B?

Definition 18.1 Discrete probability distribution $P = \{p_1, p_2, \cdots; p_1 > 0\}$ is called $\delta -$ distribution ($\delta > 0$) if there exists such ($\delta > 0$) that $P_{i+1}/P_i \geq \delta$, $i = 1, 2, \cdots;$

Lemma 18.1 *Any δ—distribution with $\delta \geq r/l$ belongs to B_r.*

Proof Let us consider $\delta-$distribution with $\delta \geq r/l$, i.e. $P_{i+1}/P_i \geq \delta \geq r/l$. As $P_{i+1}/P_i \geq r/l$, then we can choose such l_i and r_{i+1} that $P_{i+1}/P_i = (r/l)(l_i/r_{i+1})$. Similarly we can do with $P_{i+2}/P_{i+1} = (r/l)(l_{i+1}/r_{i+2})$ and so on. Other hand for any p_i we have $p_i = (p_i/p_{i-1})(p_{i-1}/p_{i-2}) \cdots (p_2/p_1)p_1$.

Hence, $p_i/p_1 =(r/)^{i-1}(l_1 l_2 \cdots l_{i-1})/r_2 r_3 \cdots r_i)$. Now it is necessary to show that for choose r_i the expression

$$\sum_{i=1}^{\infty} p_i = \sum_{i=1}^{\infty} (r/)^{i-1}(l_1 l_2 \cdots l_{i-1})/r_2 r_3 \cdots r_i) < \infty.$$

As $P = \{p_1, p_2, \cdots; p_1 > 0\}$ is probability distribution then

$$1 = \sum_{i=1}^{\infty} p_i = \sum_{i=1}^{\infty} p_i (r/)^{i-1}(l_1 l_2 \cdots l_{i-1})/r_2 r_3 \cdots r_i).$$

As $P_1 \neq 0$ hence

$$\sum_{i=1}^{\infty} (r/)^{i-1}(l_1 l_2 \cdots l_{i-1})/r_2 r_3 \cdots r_i) = 1/P_1 < \infty.$$

It is clear that any discrete probability distribution, concentrated in finite number of points is distribution from the class B_r with some $\delta = \min(P_{i+1}/P_i)$. We can choose such r, that $\delta > r/l$.

Lemma 18.2 *For arbitrary discrete probability distribution* $P = \{p_1, p_2, \cdots ; p_1 > 0\}$, *concentrated in finite number of points and* $\forall \varepsilon > 0$ *there exist* δ*—distribution* $P^\delta = \{p_1^\delta, p_2^\delta, \cdots ; p_1^\delta > 0\}$ *such, that* $\rho(P, P^\delta) < \varepsilon$.

Proof Let $P = \{p_1, p_2, \cdots ; p_1 > 0\}$ be a probability distribution, concentrated in finite number of points, i.e. there exists finite number k, such that $p_i \geq 0$, $i = 1, 2, \cdots, k$, $p_j = 0$, $j > k$. Assume that among $p_1, p_2, \cdots, p_k$ there are $p_{j1} = 0, p_{j2} = 0, \cdots, p_{jl} = 0$ where $l < k$. Consider small $\varepsilon_1 > 0$ such that $p_k - l\varepsilon_1 > 0$. Construct probability distribution $P^* = \{p_1^*, p_2^*, \cdots, \}$ such, that $p_i^* \geq p_i$ if $i \neq k, i \neq j_s, s = 1, 2, \cdots, l$; and $p_{js}^\delta = \varepsilon_1$, $s = 1, 2, \cdots, l$; $p_k^* = p_k - l\varepsilon_1$, $p_j^* = 0$, $j > k$. Then we have

$$\rho(P^*, P) = \sum_{i=1}^{k} /P_i - P_i^*/ = 2\varepsilon_1 l.$$

Hence, $\forall \varepsilon > 0$ taking $\varepsilon_1 = \varepsilon/4l$, we have $\rho(P^*, P) \leq \varepsilon/2$. Introduce new probability distribution $P^\delta = \{P_1^\delta, P_2^\delta, \cdots, \cdots, \}$ $i = 1, 2, \cdots$; for which we have $P_1^\delta = P_1^*$, $P_2^\delta = P_2^*, \cdots, P_{k-1}^\delta = P_{k-1}^*$, $P_k^\delta = \{1 - \delta/(1-\delta)P_k^*, P_{k+l}^\delta = P_k^* \delta^l\}$. If we take $\delta < \min[\min(P_i^*/P_{i-1}^*, 1/2)]$ then, $P^\delta = \{P_l^\delta, P_2^\delta, \cdots, \cdots, \}$ $i = 1, 2, \cdots$; is δ—distribution, because

$$P_{k+l}^\delta / P_k^\delta = \delta/[1 - \delta/(1-\delta)] = \delta/(1-\delta)/(1-2\delta) = \delta/(1 + \delta/(1-2\delta)) > \delta,$$

as $\delta > 1/2$. For small values of $\varepsilon > 0$ we have

$$P_k^\delta / P_{k-1}^\delta > \delta,\ P_k^\delta / P_{k-1}^\delta = P_k^\delta / P_{k-1}^\delta [1 - \delta/(1-\delta)].$$

As $P_k^\delta / P_{k-1}^\delta > \delta$ taking small value of δ we get

$$P_k^\delta / P_{k-1}^\delta = P_k^* / P_{k-1}^* \{\delta/[1 - \delta/(1-\delta)]\} > \delta.$$

Now we have to show that $P^\delta = \{P_1^\delta, P_2^\delta, \cdots\}$ $i = 1, 2, \cdots, ;$ is probability distribution. Consider

$$\sum_{i=1}^{\infty} P_i^\delta = \sum_{i=1}^{k} P_i^* - P_k^* \delta/(1-\delta) + P_k^* \delta/(1-\delta) = 1.$$

Hence,

$$\rho(P^*, P^\delta) = \sum_{i=1}^{\infty} /P_i^\delta - P_i^*/ = \delta/(1-\delta)P_k^* + \delta/(1-\delta)P_k^* = 2P_k^*\delta/(1-\delta).$$

If we take $\delta < \varepsilon/2(2P_k^* + \varepsilon)$ then, $\rho(P^*, P^\delta) = \varepsilon/2$. Thus,

$$\rho(P, P^\delta) = \sum_{i=1}^{\infty} /P_i - P_i^\delta/ = \sum_{i=1}^{\infty} /P_i - P_i^* + P_i^* - P_i^\delta/ \le \sum_{i=1}^{\infty} /P_i - P_i^*/ + \sum_{i=1}^{\infty} /P_i^* - P_i^\delta/$$
$$= \rho(P, P^*) + \rho(P^*, P^\delta) \le \varepsilon/2 + \varepsilon/2 = \varepsilon.$$

i.e. the following result is true.

Theorem 18.3 *For arbitrary discrete probability distribution* $P = \{p_1, p_2, \cdots; p_i > 0\}$ *and any* $\varepsilon > 0$ *there exists sequence of probability distribution* $Q^{(n)} = \{q_k^{(n)}, k = 1, 2, \cdots, N\}$ *concentrated in finite number of points, such that*

$$\rho(P, Q) = \sum_{i=1}^{\infty} /p_i - q_i/ < \varepsilon.$$

18.7 Geometric Distribution

Consider geometric distribution $P\{\xi = n\} = q^{n-1} \cdot p;\ p = 1 - q, n = 1, 2, \cdots$. $p_k = q^{n-1} \cdot p;\ p = 1 - q, n = 1, 2, \cdots$.

We will show that geometric distribution can be presented in the form of Eq. (18.11). Introduce $A_1 = 1, A_2 = (r/l)(l_1/r2), \cdots, A_k = (r/l)^{n-1}(l_1 \cdots l_{n-1}/r_2 \cdots r_n)$ and probability distribution $a_k = A_k/\sum_{j=0}^{\infty} A_j = A_k/A, k = 1, 2, \cdots;$ Let us put $a_1 = p_1 = p \Longrightarrow p = 1/A;\ a_2 = p_2 \Longrightarrow (r/l)(l_1/r_2) = q;\ \cdots$ $a_k = p_k \Longrightarrow (r/l)^{k-1}(l_1 l_2 \cdots l_{k=1}/r_2 r_3 \cdots r_k) = q^{k-1}$. Let us put $l_i = l^*, r^i = r^*$, $i = 1, 2, \cdots$, and denote $a = (rl^*/r^*l)$.

Then we have $a = q$. It is clear that $a \in (0, 1]$ and takes any value from (0, 1]. Hence, varying r, l, r^*, l^* for q we can get any value from (0, 1]. This means that any geometric probability distribution can be represented in the form Eq. (18.11).

18.8 Application for Traffic

Consider dependence of output capacity λ (number of transport unit, crossing fixed point on a road during unit time) on density of a road μ (number of transport unit on a unit road). This parameter is called diagram of a road. Using theorem on stationary processes we can easily to calculate output capacity and density of a road, depending on r.

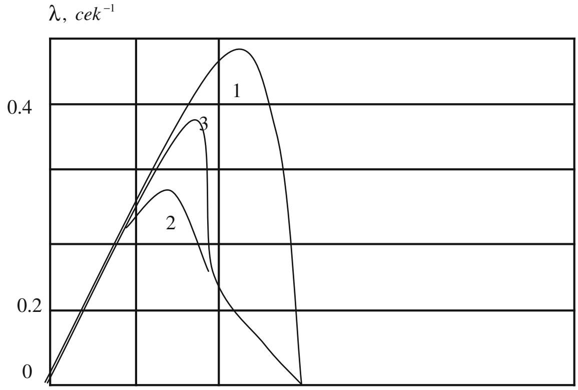

Fig. 18.4 A behavior of a road diagram

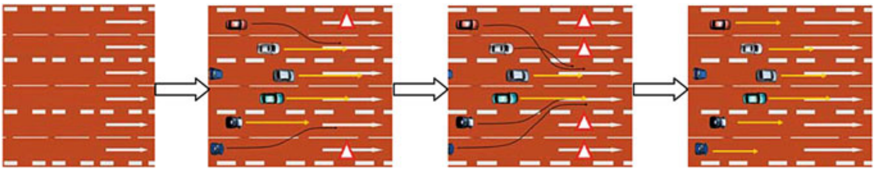

Fig. 18.5 In USA on the highway are trying to narrow a road to avoid traffic jam

$$\mu = (M\rho_{i,t}^{-1}) = \left(\sum_{k=0}^{\infty}(kd+\tau)\rho_k\right)^{-1} = \left(\tau + d\sum_{k=0}^{\infty}k\frac{1}{A}A_k\right)^{-1} = \left(\tau + d\frac{r}{l}\frac{1}{A}\frac{dA}{d(r/l)}\right)^{-1},$$

$$\lambda = r\frac{d}{h}\mu.$$

The value of τ is choosing from condition $\max_{0\leq p\leq 1}\mu = 1/\tau$, where τ means length of a transport unit. In the Fig. 18.4 a behavior of a road diagram is given. The curve 1 corresponds for the case $d = 3$; $\tau = 6.67$; $h = 0.25$; $r_0 = r_1 = r_2 = \cdots = 0.5$;

For curve 2 we take $r_0 = r_1 = r_2 = 0.1$; $r_3 = r_4 = \cdots = 0.5$ and for curve 3 $r_0 = r_1 = r_2 = 0.1$; $r_3 = r_4 = \cdots = 0.9$. (see, [7]).

Remark 18.1 It follows from Fig. 18.4 that increasing of traffic density some time leads to the growth of a road output capacity but since some value of intensity the value of output capacity goes down and leads to the traffic jam. This fact is used in many countries to avoid traffic jam. In USA on the highway are trying to narrow a road to avoid traffic jam (see Fig. 18.5).

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Chapter 19
Decision Making via Binary Decision Diagrams: A Real Case Study

Alberto Pliego Marugán, Fausto Pedro García Márquez and Jose Lorente Lavirgen

Abstract Nowadays logistical and operational systems are being more complex. A quantitative and qualitative analysis in Decision Making (DM) is presented in this paper. Decision Trees (DT) and Binary Decision Diagrams (BDD) are used to find the best solution to the main problem. The BDD method is used to perform the quantification. A real case related to the timeliness on the deliveries is studied in this paper. Importance Measures (IMs) have been considered to rank the basic events of the DT with respect to their contribution to the top event.Thereby, an improvement of the response of a company facing certain problems and the optimization of the company resources is done. Statistical data is used to obtain an approximate measure of the occurrence probability of the events involved.

Keywords Binary decision diagrams · Decision making · Decision tree · Importance measures

19.1 Introduction

The aim in a Decision Making (DM) process is to select the most advantageous path among different situations.

According to the DM problem studied in this paper, to establish a logical structure of the problem is essential. DT has been chosen for that purpose [5]. DT leads to complete a logical relation among several single events. These events, alone or by combination of them, are the responsible of the main problem. The interrelation of mentioned events has been implemented by using logical gates.

It is possible to establish which of the events need to be set employing data analysis techniques when the logical structure of the problem, as well as the statistical data,

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_19,

is considered. Nowadays the key to optimize the resources is found on these data analysis techniques considering that a wrong approach of the problem is able to make unfruitful and costly decisions.

19.1.1 Decision Making Scenario

DT shows the main problem and it is composed by several events called basic problems. These basic problems are the responsible for the main event to occur. Not all of the basic problems have the same weight and every single event has a different occurrence frequency. The DT has different levels, from the top event to the different roots, which are called basic events. It is indeed on these basic events where it will be necessary to work in order to reduce its occurrence frequency, where a lower occurrence probability of the main problem will be achieved by reducing it.

19.1.2 Binary Decision Diagram

Binary Decision Diagrams (BDDs), as a data structure that represents the Boolean functions, were introduced by Lee [4], and further popularized by Akers [1], Moret [8], and Bryant [2]. The BDD is used in order to analyze the DT. It will allow obtaining an analytical expression depending on the occurrence probability and the logical structure of the tree of every single basic event.

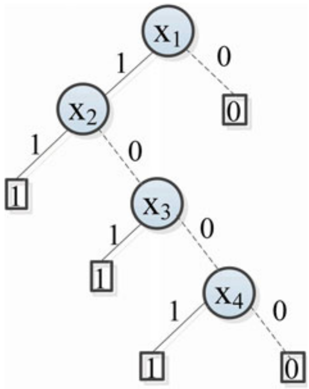
A BDD is a directed acyclic graph (V, N), with vertex set V and index set N (position of v in the order of variables). Vertex set contains two types of branches. On the one hand, a terminal vertex has as attribute a value: value(v) $\{0, 1\}$, where "1" state corresponds to the occurrence of the main problem, and "0" state corresponds to the non occurrence of the main problem. All the paths that have 1 state provide the cut-sets of the DT. On the other hand, a non-terminal vertex v has as attributes an argument index index(v) $N\{0, 1, \cdots, n\}$, and two descendants, low(v) and high(v), that are connected by a branch. Each one has a vertex 0 branch that represents a non-occurrence basic event, or 1 branch that represents an occurrence basic event. For any non-terminal vertex v, if low(v) is also non-terminal, then index(v) $<$ index(low(v)), and if high(v) is non-terminal, then index(v) $<$ index(high(v)).

BDD has a root vertex v that leads to denote a function f_v defined recursively as follow: Firstly, if v is a terminal vertex and value$(v) = 1$, then $f_v = 1$. In other case, if value$(v) = 0$, then $f_v = 0$. Secondly, if v is a non-terminal vertex with index$(v) = i$, then f_v will be:

$$f_v(x_1, \cdots, x_n) = x_i \cdot f_{\text{low}(v)}(x_1, \cdots, x_n) + x_i \cdot f_{\text{high}(v)}(x_1, \cdots, x_n). \quad (19.1)$$

The cut sets of a BDD are the pathways to terminal vertices with value of 1. The occurrence probability of the top event can be calculated by the probability of the

Fig. 19.1 BDD example



cut sets of the BDD. It is possible to achieve the occurrence probability of the main problem through the addition of the BDD cut sets. Thus, mentioned cut sets are able to be evaluated by changing the occurrence probability of each event [1, 2, 8].

Fig. 19.1 shows a BDD example, which is composed of: A root vertex: x_1; Two non-terminal vertex: x_2 and x_3; A terminal vertex: x_4.

The BDD gives (starting at the x_1 event and finishing in every path to the ones) the cut sets needed, which indeed are:
$CS_1 = \{x_1, x_2\}$,
$CS_2 = \{x_1, \overline{x}_2, x_3\}$,
$CS_3 = \{x_1, \overline{x}_2, \overline{x}_3, x_4\}$,
where $\overline{x}_i$ is the denial of x_i, which means the non occurrence of that event.

19.1.3 Conversion from DT to BDD

The transformation from DT to BDD is achieved by applying certain mathematical algorithms [7]. Hence, it is possible to find an analytical expression of the logical structure desired.

An adequate ranking of the basic events is crucial in order to reduce the size, and thus the computational time to solve the BDD. There are different methods, and any of them will be more adequate to use according to the problem structure, number of variables, etc. In the simulations done in this paper, the AND method have been considered for listing the events [6].

Once the conversion from DT to BDD is done, it is possible to obtain an accurate expression of the main problem occurrence probability by assigning a probability value to each basic event.

$$Q_{sist} = q_{e001} \cdot q_{e002} + q_{e001} \cdot (1 - q_{e002}) \cdot q_{e003} + q_{e001} \cdot (1 - q_{e002}) \cdot (1 - q_{e003}) \cdot q_{e004}, \tag{19.2}$$

where Q_{sistis} the occurrence probability of the main problem and q_{e00i} is the probability of occurrence of the basic event 'i'. Further detailed information about the conversion and variable ordering methods can be found in [4].

19.1.4 Importance Measures

A classification and identification of the events that are influencing the most in the main problem is necessary. IMs reveal some key information such as which of the events are the ones that contribute the most to the main problem to occur.

IMs can be calculated by the Birnbaum, Criticality and Fussell-Vesely heuristic methods. The basic events with higher IM values must be the first to be considered [3]. Focusing on the events that IMs are pointing, will allow the company to reduce the probability of the main problem.

Birnbaum Importance Measure determines that the system is in a certain state that, the occurrence of a certain event causes the main problem. The mathematical expression is:

$$I_i^{\text{Birn}} = Q_{\text{sis}}(1_i, q(t)) - Q_{\text{sis}}(0_i, q(t)) = \frac{\partial Q_{\text{sis}}(t)}{\partial q_i(t)}, \tag{19.3}$$

where Q_{sis} is the unavailability of the system, $Q_{\text{sis}}(1_i, q(t))$ is the probability of occurrence of the main problem when the basic event "i" is happening, and $Q_{\text{sis}}(0_i, q(t))$ is the probability of occurrence of the main problem when the basic event "i" is not happening.

Criticality Importance Measure, unlike Birnbaum, considers the probability of the related basic event:

$$I_i^{\text{Crit}} = \left(\frac{q_i}{Q_{\text{sis}}}\right) \cdot \left(\frac{\partial Q_{\text{sis}}}{\partial q_i}\right) = \left(\frac{q_i}{Q_{\text{sis}}}\right) \cdot I_i^{\text{Birn}}, \tag{19.4}$$

where Q_{sist} is the occurrence probability of the main problem and q_i is the probability of occurrence of the basic event 'i'.

Fussell-Vesely Importance Measure is that corresponding to the union of those cut sets where such events are presented.

$$I_i^{FV} = \frac{P(E_1{}^i \bigcup E_2{}^i \bigcup E_3{}^i \cdots E_n{}^i)}{Q_{\text{sis}}(t)}, \tag{19.5}$$

where $(E_1{}^i \bigcup E_2{}^i \bigcup E_3{}^i \cdots E_n{}^i)$ is the probability of the union of those cut sets where basic event i is presented and $Q_{\text{sis}}(t)$: Main problem occurrence probability.

19.2 Case Study

This paper is focused on the reduction of the occurrence probability of an undesired main event in a decision making scenario. Mentioned event is defined by the orders delay. Firstly, detect which are the events related with the delay in the orders is compulsory (see Fig. 19.3). In order to have an efficient and real decision making, the development of the DT flowchart is crucial. The closest to real decisions the tree is, the better the results will be achieved.

An inner procedure must be in charge of compiling all the information of the basic events. The connections between the events and the logical structure will be obtained by analyzing this information. Mentioned inner procedure need to be done carefully with surveys, questionnaires, meetings and anything needed to create a feedback between employees and the company. The probability associated to each basic event is taken from mentioned feedback and questionnaires.

A repeated event in the DT is possible to be found. This is due to there are basic events which are able to cause the main problem in numerous company areas. For instance in this real case study "Sampling mistakes" (*e*006) is repeated in first and third branches.

Minimal cut sets are obtained by using a mathematical algorithm which converts the DT to BDD as aforementioned in previous sections. Figure 19.2 shows the basic events interrelation and the probability of occurrence of each basic event. The following calculations have been obtained starting from mentioned probability of occurrence.

19.2.1 System Probability Variation Over the Years

A simulation of the system through ten years has been done. The simulation consists on decreasing the probability of each single event in isolation. With this simulation, a more restrictive control of the influence of each basic event over the system is achieved.

According to the results presented in Fig. 19.2, basic events number ten, from eighteen to twenty-three, twenty-six and twenty-seven, are the ones which affect the most to the system. That means that those events must be modified if the purpose of the company is to reduce efficiently the main event probability. These results will be verified straightaway with the IMs analysis.

Figure 19.4 shows the importance of each event with the three IM methods. These events can be grouped in a ranking of importance. In this particular case, the event twenty-six has a greater importance than the rest of the events. That means it should be the first event to be considered. However, there is a group of events which has a similar IM value among them (events ten, eighteen to twenty-three and twenty-seven). It is useful to observe the three IMs values to decide how events will be placed in the importance ranking.

Delay in the orders

Projects interaction	**g001**	OR	**Projects interaction**	g001	AND	**Human Resources**	g007	OR	**Lack of notification**	g013	OR	**Detailed needs in organization chart**	g017	OR	**Delay in repair orders**	g019	OR
Human Resources	**g007**		Wrong stock project	g002		Renege on inner procedures	g008		Unreal warehouse data	g014		Mismatch between needs	g018		Tools shortage	g020	
Lack of advice	**g013**		Wrong information exchange. P=0.04	e001		Bad diet	g009		Wrong simulations	g016		Unreal capacity work P=0.1	e020		Errors in paperwork generation	g022	
Detailed needs in organization chart	**g017**		Wrong stock project	g002	AND	Renege on inner procedures	g008	OR	Unreal warehouse data	g014	AND	Mismatch between needs	g018	AND	Manufacturing closed late	g023	
Delay in repair orders	**g019**		Poor production management	g003		Lack of employees formation	g005		Theft employees. P=0.12	e014		Overcharge of capacity. P=0.05	e018		Tools shortage	g020	OR
			Lack of a global planning. P=0.03	e002		Lack of motivation	g010		No coordination between workers	g015		Wrong work planning. P=0.07	e019		Wrong hierarchy of employees. P=0.02	e021	
			Poor production management	g003	OR	Lack of employees formation	g005	AND	No coordination between workers	g015	OR				Wrong tools stock	g021	
			Forecast mistakes	g004		Employees with low qualification	e004		Poor communication with work orders. P=0.13	e015					Wrong tools stock	g021	AND
			Lack of personal formation	g005		Lack of inner formation courses	e005		Lack of daily notification. P=0.2	e016					Limited tools. P=0.03	e022	
			Forecast mistakes	g004	AND	Lack of motivation	g010	AND	Wrong simulations	g016	AND				Low tools reliability. P=0.1	e023	
			Shortage of statistic resources	g006		Limited salary. P=0.07	e009		Lack of simulations. P=0.03	e017					Paperwork generation errors	g022	AND
			Out-dated analysis techniques. P=0.05	e003		Bad work atmosphere. P=0.08	e010		Forecast mistakes	g004					Employees with limited qualification. P=0.1	e024	
			Shortage of statistic resources	g006	OR	Bad diet	g009	OR	Forecast mistakes	g004	AND				Lack of resources in some departments. P=0.2	e025	
			Sampling mistakes. P=0.08	e006		Personal reasons. P=0.06	e008		Out-dated analysis techniques. P=0.05	e003					Manufacturing closed late	g023	OR
			Parameters selection mistakes. P=0.08	e007		Poor canteen	g011		Shortage of statistic resources	g006					Limited connection between departments. P=0.3	e026	
			Lack of employees training	g005	AND	Poor canteen	g011	AND	Shortage of statistic resources	g006	OR				Manufacturing order not scheduled. P=0.06	e027	
			Employees with low qualification. P=0.06	e004		Menu variety. P=0.06	e011		Sampling mistakes P=0.08	e006							
			Lack of inner formation courses. P=0.02	e005		Food quality	g012		Parameters selection mistakes P=0.08	e007							
						Food quality	g012	OR									
						Low kitchen personnel qualification. P=0.05	e012										
						Low ingredients quality. P=0.04	e013										

Fig. 19.2 Delay in the orders DT description

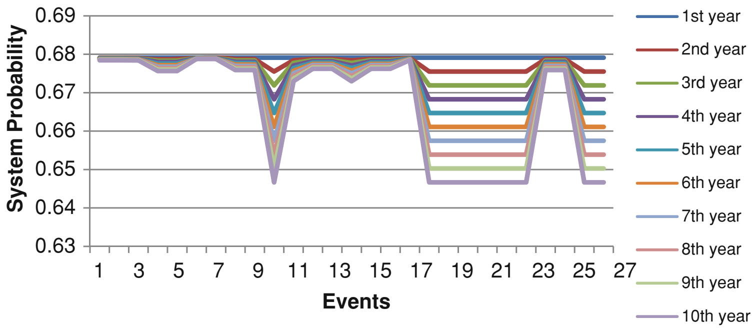


Fig. 19.3 Influence of basic events over the years

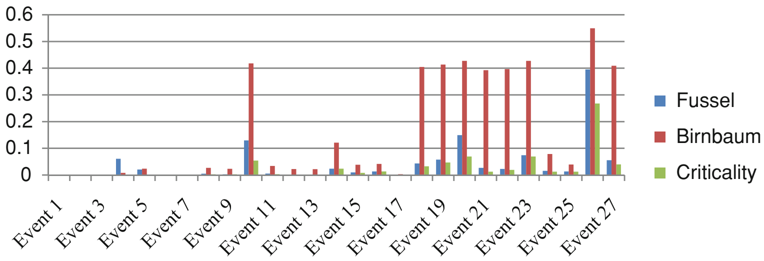


Fig. 19.4 Importance Measures

The IM value of the rest of the events is so small that they will not have to be considered until the events with the higher IM value had been solved. With this valuable information, it is possible to apply a methodology whereby to obtain a ranking showing the order of the basic events to act.

Looking for the most efficient way to act, it is suggested to start with Criticality IM. In case the basic events have the same IM value, the second step would be to obtain the Birnbaum IM and rank the events. In case the basic events still have the same importance, finally Fussell-Vesely should be obtained and thus have an importance order of the basic events.

19.3 Conclusions

A quantitative analysis in DM problems provides efficient and useful results, e.g. to determinate the basic events that have major influences. Furthermore, to establish a logical structure of the problem is necessary in order to respond as close as possible to the manner the problem is caused.

BDDs are employed to obtain the cut sets that are used to get the analytical expression of the main problem occurrence probability. Thus, the DM offers the chance to simulate dynamically the probability of the main problem when the probabilities of the basic events changeover time.

Decrease the probability of certain events simultaneously entails a lower impact over the main problem probability than to decrease only the probability of the events which the IMs are pointing as more important.

Applying aforementioned methodology provides the company with a powerful method in the DM process and also an approach to increase the reliability.

As further work the author propose to explore large DM problems, and more complex problems where consider other variables.

Acknowledgments The work reported herewith has been financially supported by the Spanish Ministerio de Economíay Competitividad, under Research Grant No. DPI2012-31579.

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Chapter 20
Portfolio Delivery Approach to Township Sewage Treatment Facilities in China: A Case Study

Chuan Chen, Nini Wu and Igor Martek

Abstract The wide need for sewage treatment facilities at the township level across China implies an emerging niche market for water and sanitation developers, investors and financiers. However this potential market is difficult to enter with traditional financing and delivery methods, because township sewage features small amount, volatile quantity, geographically scattering, immature fee charging system, weak affordability, and lack of capacities. A group of concession sewage treatment projects collectively implemented by a private company in the Changsha County of Hunan Province under the so called 'Changsha Model' provided innovative solutions. This cases study first examined the portfolio approach in terms of multiple delivery method integration, technology, and centralized control system, and evaluated the replicability of the new model. Practices and lessons learned from the case were then presented and summarized that can be applied to the following township sewage treatment facility development. Last, the Changsha Model was compared with similar infrastructure portfolio delivery solutions applied in the US.

Keywords Infrastructure · Portfolio delivery method · China · Sewage treatment

20.1 Introduction

An unprecedented large scale of urbanization and industrialization are occurring in China. The total urban population of this country of 1.3 billion people has increased from 570 million in 2005 to 607 million in 2008 [1] and is expected to increase to 925 million in 2020 [2]. As the world's manufacturing hub, China is now the largest

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_20,

consumer of coal and petroleum in the world. As a consequence, China has to fight a long and difficult war against overwhelming environmental pollution. In the sewage treatment sector, according to the National Development and Reform Commission [7], by the end of the 11th five year plan period (2010), there were 2832 sewage treatment plants in China, with a total treatment capacity of 125 million cubic meters per day, 108 % higher than the 2005 level. The Ministry of housing and Urban-Rural Development 2012 [7] released that by 2010, urban sewage treatment ratio of the country reach 82.31, 26 % above the 2006 level. By 2010, sewage treatment plants have been set up in over 90 % cities. The figures might imply that the sewage treatment market of China is close to saturation. However, there are still niches of the market which call for significant investment, such as sewage treatment at township levels across the country. So far most of the sewage treatment plants are undertaken at the municipal and county levels, remarkable needs from the large amount of townships are still out of the radar of most water and sanitation developers. Decision makers of China are now paying their attention to this domain. According to Wang [8], in the twelfth Year Period, China will increase its total sewage treatment capacity by 60 million tons per day and over 3,000 new treatment plants will be built mainly for towns and rural areas.

This highly potential niche market is, however, very difficult to access, particularly to private developers and investors who lack support from government and financers and are profit driven and risk averse. At the township level, sewage is mainly from households and the volume is usually small and volatile. Any traditional way to centralize sewage collection and processing in a jurisdiction like county proved to be financial invalid. Other impeding factors against entry into the market include (1) that at township level most residents still believe sewage treatment is a public welfare and should not be paid for; (2) that towns often have poor land use plan and the Greenfield plant has to occupy farmland which is tightly controlled by the government; and (3) unavailability of human resources for construction and operation in remote places. There is therefore a demand for innovative financing ad project delivery methods that can interest and enable water and sanitation developers and investors to participate in the township sewage treatment market. In this regard, a recent development project in the Changsha County of Hunan Province sponsored by a local private company provides such a model that is very worthy of investigation for good practices and lessons learned.

20.2 Background

As one of the most developed countries of China (one of the "Hundred Most Competitive Counties of China"), the Changsha County of Human Province suffered serious pollution. All the towns in the jurisdiction in total produced 25 million tons of sewage per year without any effective treatment, and the sewage was directly discharged to adjacent ponds, rivers, and reservoirs. In September 2008, the Changsha Municipal Government enacted the Changsha City Environment Protection Three

Year Action Plan (2008-2010), which specified that within three years, the Changsha City would improve township sewage treatment ratio by establishing new facilities and by the end of 2010, 40 % towns of the City should have their own sewage treatment plants. To this end, the Changsha County Government tentatively approached some water affairs companies to explore their interest in carrying out the portfolio of the 18 sewage treatment plants, but responses they received were not positive. Most of these companies were only interested in the construction works. Those few showing interest in operation however offered very high base tariffs.

Then a Beijing based private company Sound Group touched based with the County Government and took part in the bidding process. Without encountering much competition, Sound Group won the bid with a proposed base treatment price of 1.09 Yuan per ton. On January 28, 2011, Sound Group signed the concession agreement with the Changsha County Government on the portfolio. Under the agreement, Sound Group would finance and build 16 sewage treatment plants with a total capacity of 29,400 tons per day and operate them together with 2 existing plants with a total capacity of 5,000 tons per day for 30 years and then transfer them back to the local government free of charge. In addition, Sound Group needed to build peripheral pipeline networks at its own cost and subsequently transfer these facilities to the local government once they were finished and would get paid in three instalments within five years. Sound Group was also the Engineering-Procurement-Construction (EPC) Contractor to implement the greenfield projects in the portfolio. Construction would take 10 months and operation was expected to begin by the end of December 2011. The total investment by Sound Group was estimated to be 275 million Yuan.

20.3 Project Portfolio Solutions

Sound Group's portfolio delivery method involves application of various project delivery methods to the project portfolio, innovative technologies specific to smaller township treatment plants and a highly integrated operation and maintenance mechanism. Because it was first explored and undertaken in the Changsha County, the new model is called by the media as "Changsha Model".

20.4 Integration of Multiple Delivery Methods

Regarding the portfolio, Sound Group applied Build Own Operate Transfer (BOOT) method to the 16 greenfield plants, Build-Transfer (BT) method to the connection and distribution pipeline networks, management contract to the two existing plants, and Engineering Procurement and Construction (EPC) to the implementation of the whole facilities. Under the BT method the local government took care of the cost for construction of the pipeline networks. The management contracts brought about cash flow right away. Hence the financing pressure on the sponsor was minimized.

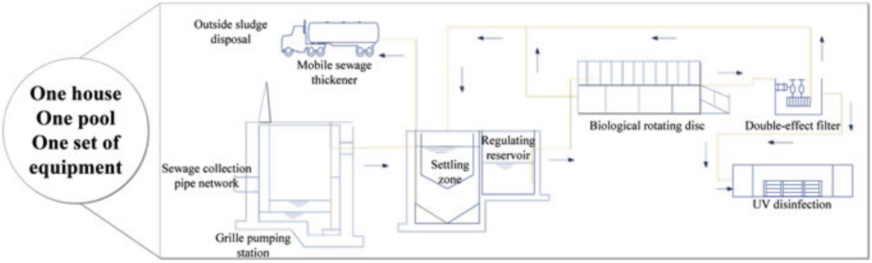

Fig. 20.1 The SMART system (*Source* sound group)

The EPC contracts enabled Sound Group to make the best of its in-house engineering, equipment production and construction abilities and further enhance control and earn profit from peripheral works.

20.5 SMART System

A patent processing technology solution, SMART, developed specifically for smaller township sewage treatment plants was applied to all the 16 greenfield projects to facilitate management and operation and meanwhile reduce operation cost.

The SMART system was developed based on independent research by Sound Group. The core of the system is the biological rotating disc. A treatment plant adopting the SMART system is visually made up of three parts, 'one house, one pool, and one set of equipment' as shown in Fig. 20.1.

A sewage treatment plant based on the SMART system needs less land. For example, the Huanghua Town Sewage Treatment Plant, which has a capacity of 8,000 tons per day, occupies only 9 acres of land. A township treatment plant based on the SMART system usually needs a site 30–40 % less than a plant using current technologies. However the amount of saving is a parabola associated with the treatment scale: the larger the scale the more land can be saved; when the scale of the plant reaches 10,000 tons per day, the land saving peaks.

The treatment equipment is packaged into cells (i.e., modules) with a uniform capacity of 500 tons per day. The numbers of cells to be needed depends on the actual capacity of the plant. As in the above example of the 8,000 tons per day plant in Huanghua Town, 16 cells were installed. The modularized treatment facilities means that the whole plant is easy and quick to install, maintain, expand, and dismantle. Also when a plant is out of use, the cells can still be reused elsewhere.

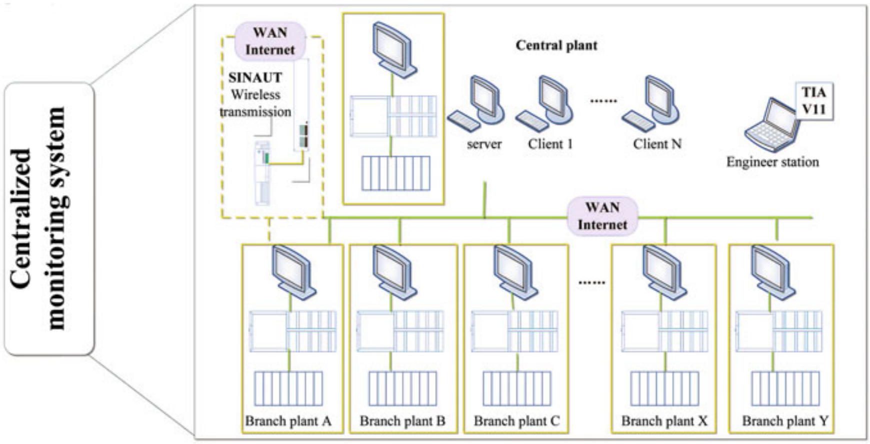

Fig. 20.2 The plant control centre setting (*Source* sound group)

20.6 Decentralized Processing and Centralized Control

In the Changsha portfolio, a centralized control centre (see Fig. 20.2) oversees all 18 plants. There is also a central sludge treatment centre for disposing sludge collected from all plants and a central water quality test lab.

The centre is located at Huanghua Town Sewage Treatment Plant (see Fig. 20.3). Only one worker is assigned to each plant, and all technical staff members are based at the central control, responding to emergency calls from the plant watch. Thus, the operation cost is minimized.

20.7 Replicability

Changsha County is one of the most developed counties in China, so affordability of the treatment facilities is not a big issue, but whether the Changsha model can be replicated remains a question.

According to an interviewed government official, the Changsha Mode can be copied to less rich regions, because the cost can keep to be low. The total cost of the Portfolio consists of three main parts: land use and civil engineering, equipment procurement and installation, and pipe network construction. Among them, cost on equipment is mainly contingent upon the design treatment capacity and can only vary in a small range. Significant cost saving can still be achieved regarding the other two parts under the Changsha Model.

There are however still some hard conditions that must be met from the viewpoint of Sound Group. Mr. Wen Yibo, the CEO of the Company asserted that the town and village where Changsha Mode can be applied should meet three conditions: first,

Fig. 20.3 Central control of the treatment plants

sound fiscal status of the local government; second, integrated charging system for both water supply and sewerage treatment which can ensure the collection of sewerage treatment fees; and third, commitment of the local government. Nevertheless, Wen is confident that with economic development and increasing attention attached to environmental protection by the public, more and more towns and villages can meet these conditions. As a matter of fact, Sound Group is currently undertaking similar portfolios in several provinces including Liaoning, Jiangsu, Shanxi, Hubei and Guizhou.

20.8 Discussion and Conclusion

The packing of multiple township level sewage treatment plants in a single contract by integrating various project delivery methods is the first of its kind in China. The Changsha Model provides a way that enables private companies to develop and/or manage smaller and geographically scattered sewage treatment projects at town level which used to lack economic and financial feasibility by capitalizing on economy of scale.

The concept of infrastructure portfolio delivery method is however not new. Studies on integrated portfolio delivery systems were largely pioneered by Professor John Miller of the Massachusetts Institute of Technology (MIT). In his research [3–6], Miller examined the complementarities between and among different traditional and emerging delivery and financing methods and developed portfolio solutions for multiple transport and water projects in the context of the USA, mainly from the perspective of the government. Miller emphasized that government, in its role of ensuring ongoing maintenance and upgrading of a complex portfolio of existing infrastructure while being required to add ever new infrastructure, must find ways to optimize the financial performance of the totality of infrastructure under its care as a unified portfolio. Moreover, apart from funding sources, timing of project starts and the scheduling of project milestones have significant impact on cash-flow. Infrastructure portfolios need to be managed in such a way that as certain projects come on line and begin generating revenue streams, other projects can be initiated to utilize that stream without necessitating massive draw downs of alternatively sourced funds. Such alternate funds may simply be not available, or may come at a high borrowing cost. Managing a portfolio of infrastructure with its various streams of positive and negative cash flow needs to be brought into balance in ways that maximize project deliveries without compromising financial stability; both of the private participants, as well as government.

The 'Sound Group' project delivery approach represents a significant departure from the approach identified and recommended by Miller. Rather than structuring project delivery around cash-flow management, 'Sound Group's' core strategy is simply to pare total costs. This it does through consolidation of all the town level waste-water projects under a centralized control, operations and maintenance function. The project infrastructure is custom state-of-the-art systems that are minimally dependent on hard equipment, and which can therefore be sited on relatively small land holdings. The uniformity of the various waste-water treatment plants across Changsha County makes it possible to limit delivery methods to four: Build-Own-Operate-Transfer (BOOT), Build-Transfer (BT), management contract, and Engineering-Procurement-Construction. Delivery would be all the more stream-lined if it were not for the fact that the Changsha Government required the integration of existing brown-field projects with green-field. Moreover, the homogeneity of the individual township waste-water treatment facilities, combined with their wide geographical distribution, lends the project to technical rather than financial engineering. In short, 'Sound Group' drives the project on the basis of minimization of capital asset requirements at each treatment plant, while reducing on-going operational costs through lean, scale-based, remote centralized management.

Miller's portfolio approach addresses the US's large but aging infrastructure inventory under conditions of diminishing public financial resources. The 'Sound Group' approach addresses China's need for low cost, new infrastructure provision under conditions of long-term governmental policy and market uncertainty. Over time, as China's infrastructure inventory matures, financial portfolio considerations can also be expected to play a greater role in future China infrastructure delivery systems. But the lessons from 'Sound Group's experience may also inform project delivery strategies in other regions of China, and other countries; particularly in emerging economies.

Acknowledgments Completion of this paper is attributed to the kind help and support of Beijing Sound Group which hosted the site visit and shared a lot of valuable data and insights, and the financial support from the National Natural Science Foundation of China (NSFC) under the project No. 71371131.

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Chapter 21
Research on the Design of the Selective Contract Under SMEs' Financial Demand

Sheng Zhong, Bingjie Luo and Yunfeng Zhao

Abstract In traditional loan agreements, because of adverse selection, banks will worry that bad SMEs will easily imitate as good SMEs to get extra income, so the interests of banks will be lost, as a result banks do not want to provide loans for SMEs. In this article, first, we analyze the effects of adverse selection for SMEs' financial demand. Then we study the selective contract under the condition of industry lending. We can see that selective contract can avoid the damage caused by adverse selection and make tripartite win for banks, loan companies and guarantee enterprises. The conclusions we made in this paper have a good value for SMEs lending practices.

Keywords Industry lending · Adverse selection · Selective contract

21.1 Introduction

With the development of economy, SMEs play an important role in stimulating economic growth, increasing tax revenue, promoting innovation and stabilizing urban employment. However, financing problem has become an obstacle for the development of SMEs. Now, the financing problem of SMEs can be seen in different countries around the world, and the main reason is information asymmetry. Loan companies have some private information that banks do not know, so banks have to face the risk of adverse selection when they loans. For the perspective of risk control, banks tend to lend to large corporations which they know them better, while SMEs can not get loans even if they have positive net income. The existence of adverse selection is also a huge problem for SEMs since they do not have enough money to invest in some projects without the help of banks. Study how to overcome the adverse selection has great realistic meaning that can help reach more loan agreements between banks

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_21,

and loan companies. Furthermore, finding out a new way of financing also has good value for SMEs lending practices.

At present, the study of financing problem is mainly based on using collateral to save credit rationing. Stiglitz and Weiss [6] were the earliest people who studied the case of credit rationing under asymmetric information. Because of information asymmetry between banks and enterprises, the credit markets must face the risk of moral hazard and adverse selection. Banks used credit rationing rather than raising interest rates to avoid risks. Zhang [9] based on the perspective of asymmetric information, analyzed the causes of the problem of financing for SMEs. Ghosal and Sokol [2] illustrated the impact of adverse selection on the markets through the “lemon market” model. Duran and Lozano-Vivas [1] studied that adverse selection would increase the risk of banks’ loans, while with the help of banks’ balance sheets they could reduce the risk. Handel [3] developed and estimated a choice model in the field of insurance. According to the model we could change some provisions in agreements to identify different firms. It could help us to avoid adverse selection in field of insurance. Jia [4] demonstrated in a model that firms could be credit-constrained due to aggregate uncertainty because financial institutions face high borrowing costs during economic downturns, and the government could offer insurance in the form of loan guarantees to ease borrowing constraints for SMEs. Ma and Tirole [5] developed the theory of contract design by informed party. Zhang [8] researched that when the screening mechanism established, there was an optimal separation contract under asymmetric information.

The above researches are mainly concentrated in terms of loan contract designed by banks. Actually they have less information about SMEs. If SMEs want to get some money to star their items, usually they have to pledge their assets for banks. In traditional loan agreements, the pledge that banks need are often too high to offer. Most of the researches are about collateral offered by loan companies themselves or professional security companies. Research in contract designed by SMEs who have more information about themselves and can design selective contracts under the condition of industry lending to show the different between good SMEs and bad SMEs is less involved. In this paper, first, we analyze the effects of adverse selection for SMEs’ financial demand. Then we study the selective contract under the condition of industry lending. By doing this, we can separate good or bad companies, so as to achieve the purpose of prevention the risk of adverse selection. The aim of this paper is to make tripartite win for banks, loan companies and guarantee enterprises.

21.2 Model Background

A SME has a project on a fixed investment, the SME’s own funds is A. Information such as overall strength and the likelihood of success of the project which will affect the return for banks are only known by loan company. The loan company can be divided into the good or bad one according to private information.

Table 21.1 Revenues for bank, loans, guarantees under the condition of industry lending

		Total	Bank	Loans	Guarantees
Success	Due diligence	R	R_1^i	R_b^i	$R_g^i - x$
	Shirk	R	R_1^i	$R_b^i + b$	$R_g^i - x$
Fail	Due diligence	C	$\beta_g C$	0	$(1-\beta_g)C - x$
	Shirk	C	$\beta_g C$	b	$(1-\beta_g)C - x$

Assume that the probability of project success for good one (strong, good technology) is P_H^G (when the good one due diligence) or P_L^G (when the good one shirk). The probability of project success for bad one (weak, poor technology) is P_H^B (when the bad one due diligence) or P_L^B (when the bad one shirk). Apparently, $P_H^G > P_L^G, \triangle P^G = P_H^G - P_L^G, P_H^B > P_L^B, \triangle P^B = P_H^B - P_L^B$.

When choose to shirk, company can has a private gain for B. The total investment for the purchase of raw materials is I. The SME does not has enough money ($A < I$), needs to ask bank for help, and bank will face adverse selection risk.

Under industry lending, two SMEs build up a lending relationship in which one is a loan company the other is a guarantee company. Guarantee company has the obligation to supervise, making loans shirking private gain from B down to b ($b < B$), but needs to pay the monitoring costs x. If the project success, there is no salvage value and total revenue is R; if the project fail, the remaining raw materials or unfinished products have a salvage value for C. Making the salvage value as guarantee, due to the similarity of raw materials demand or other aspects in the same industry, assuming C will not be devaluated under the condition of industry lending. When the project fail, the loan company sends the salvage to the guarantee company, and the guarantee company should pay $\beta_g C$ $(0 < \beta_g < 1)$ for bank.

Table 21.1 shows the revenue for bank, loan SME, guarantee SME under the condition of industry lending. In Table 21.1, $R = R_1^i + R_b^i + R_g^i (i = G, B)$.

To make loans due diligence, bank agrees to loan, guarantees meets participation constraint and supervision constraint, in the condition of $A < I$, modeling:

$$\max P_H^i \cdot R_b^i - A$$
$$\text{s.t.} \begin{cases} P_H^i \cdot R_b^i \geq P_L^i \cdot R_b^i + b \\ R_H^i (R - R_b^i - R_g^i) + (1 - P_H^i)\beta_g C \geq I - A \\ P_H^i \cdot R_g^i + (1 - P_H^i)(1 - \beta_g)C - x \geq 0 \\ P_H^i \cdot R_g^i + (1 - P_H^i)(1 - \beta_g)C - x \geq p_L^i \cdot R_g^i + (1 - p_L^i)(1 - \beta_g)C. \end{cases} \tag{21.1}$$

Take calculated equals for Eq. (21.1), get the results $R_b^i = \frac{b}{\triangle p^i}, R_g^i = \frac{x}{\triangle p^i} + (1 - \beta_g)C$. So, $A \geq \bar{A}^i = P_H^i \cdot \frac{b}{\triangle p^i} - (P_H^i \cdot R - I) - (1 - P_H^i)\beta_g C + P_H^i \left[\frac{x}{\triangle p^i} + (1 - \beta_g)C\right], (i = G, B)$.

If bank knows the type of loans, when the loan company has own funds over $\bar{A}^i$ loans can get money. However, the fact is that bank does not know the type of the loan company.

This paper studies the loan agreement set by the loan company, the bank choose to accept it or not.

Assuming the loan company and the bank are risk neutral and there is no time preference, the bank is in a state of perfect competition so its expected rate of return of investing is 0, the loan company's income could not be negative under the protection of limited liability.

21.3 Adverse Selection Effects For SMEs

Bank does not know whether the loan company is a good or bad one, just know that the probability of good is α, and the probability of bad is $1-\alpha$. Assuming good and bad loans' success probability are p, q $(p > q)$ respectively. They have the same own funds A.

When there is no adverse selection, modeling:

$$\begin{aligned} p(R - R_b^g) = I - A \Longrightarrow p \cdot R_b^g = pR - (I - A) = V, \\ q(R - R_b^B) = I - A \Longrightarrow q \cdot R_b^B = qR - (I - A) = \hat{V}. \end{aligned} \tag{21.2}$$

$V, \hat{V}$ are returns for loans, in the above case both good and bad loans will be given loan.

In the case of adverse selection, bank does not know the type of loans, if good one can get a loan and ask for $R_b^g = \frac{V}{p}$ as a return, then bad one can imitate as good one to get a return for $R_b^g = \frac{V}{p}$. According to (21.2), we see: $q(R - R_b^G) = qR - \frac{q}{p}(I - A) > qR - (I - A) = \hat{V}$.

Therefore, by imitating as a good one, bad one can reduce the pay to bank and increase its expected return. However, bank can expect this "confused behavior": $[\alpha p + (1-\alpha)q](R - R_b^G) < I - A$.

So bank will refuse loans in the condition of adverse selection. Less information that bank has will make loan become difficult.

21.4 Selective Contract

21.4.1 Design Concept

Under the industry lending, the guarantee company knows the type of the loan company. Bank is faced with a contract $(c, \tilde{c})c$ including the bank's return R_1^G, the loan company's return R_b^G, the guarantee company's return R_g^G when good loan company success; $\tilde{c}$ including the bank's return R_1^B, the loan company's return R_b^B, the guarantee company's return R_g^B when bad loan company success. Contract $(c, \tilde{c})$ is proposed by the loan company, bank chooses to accept it or not. Good loans prefers c while bad one prefers $\tilde{c}U_b(c)$ and $\tilde{U}_b(c)$ represent the revenue for good and bad loans under contract c; $U_b(c)$ and $\tilde{U}_b(c)$ represent the revenue for good and bad loans under contract $\tilde{c}$; $U_1(c)$ and $\tilde{U}_1(c)$ represent the revenue for bank when it faces two difference loans under contract c; $U_1(\tilde{c})$ and $\tilde{U}_1(\tilde{c})$ represent the revenue for bank when it faces two difference loans under contract $\tilde{c}$.

Assuming both good and bad loans have the same own funds A and $A \geq \bar{A}_i$ $(i = G, B)$. Because the type of loans is not observed by bank, good type can always be imitated, in order to prevent the good one to be imitated, the contract $(c, \tilde{c})$ must meet the following principles of incentive compatibility: $U_b(c) \geq U_b(\tilde{c})$ and $\tilde{U}_b(\tilde{c}) \geq \tilde{U}_b(c)$.

In the case of incentive compatibility, assuming the contract $(c, \tilde{c})$ is individually profitable: $U_1(c) \geq 0$ and $\tilde{U}_1(\tilde{c}) \geq \tilde{U}_b(c)$, so $\alpha U_1(c) + (1-\alpha)\tilde{U}_1(\tilde{c}) \geq 0$.

Under the principles of incentive compatibility and individually profitable, if the bank has an expected for the loan company's type, then through selectively contract under industry lending can make the loan company maximize revenue, get money smoothly.

21.4.2 Theoretical Basis

When there is no industry lending, according to Tirole [7], under the principles of incentive compatibility and individually profitable, if c_0 maximize gains for good loans, then $U_b(C_0)$ is its best low information density, which is the maximum guaranteed income for good one. Modeling:

$$\max_{\{c,\tilde{c}\}} U_b(c_0)$$
$$\text{s.t.} \begin{cases} U_b(c) \geq U_b(\tilde{c}) \\ \tilde{U}_b(\tilde{c}) \geq \tilde{U}_b(c) \\ U_1(c) \geq 0 \\ \tilde{U}_1(\tilde{c}) \geq 0. \end{cases} \tag{21.3}$$

If $\tilde{c}_0$ maximize gains for bad loans, then $\tilde{U}_b(\tilde{c}_0)$ is its best low information density, which is the maximum guaranteed income for bad one. Modeling:

$$\max_{\{c,\tilde{c}\}} \tilde{U}_b(\tilde{c}_0)$$
$$\text{s.t.} \begin{cases} U_b(c) \geq U_b(\tilde{c}) \\ \tilde{U}_b(\tilde{c}) \geq \tilde{U}_b(c) \\ U_1(c) \geq 0 \\ \tilde{U}_1(\tilde{c}) \geq 0. \end{cases} \tag{21.4}$$

Jean · Tirole confirmed that loan companies can be guaranteed to get the best low information density when lending.

The study by Jean · Tirole is in a circumstance without industry lending when there is industry lending, Eqs. (21.3) and (21.4) also need to meet the participation constraint and the supervision constraint for guarantees. Modeling:

$$\max_{\{c,\tilde{c}\}} U_b(c_0)$$
$$\text{s.t.} \begin{cases} P_H^G \cdot R_g^G \geq P_H^G \cdot R_g^B \\ P_H^B \cdot R_g^B \geq P_H^B \cdot R_g^G \\ P_H^G(R - R_b^G - R_g^G) + (1 - P_H^G)\beta_g^C \geq I - A \\ P_H^B(R - R_b^B - R_g^B) + (1 - P_H^B)\beta_g^C \geq I - A \\ P_H^G \cdot R_g^G + (1 - P_H^G)(1 - \beta_g)C - x \geq 0 \\ P_H^G \cdot R_g^G + (1 - P_H^G)(1 - \beta_g)C - x \geq P_L^G \cdot R_g^G + (1 - P_L^G)(1 - \beta_g)C \\ R = R_1^G + R_b^G + R_g^G \end{cases} \tag{21.5}$$

and

$$\max_{\{c,\tilde{c}\}} \tilde{U}_b(\tilde{c}_0)$$
$$\text{s.t.} \begin{cases} P_H^G \cdot R_g^G \geq P_H^G \cdot R_g^B \\ P_H^B \cdot R_g^B \geq P_H^B \cdot R_g^G \\ P_H^G(R - R_b^G - R_g^G) + (1 - P_H^G)\beta_g^C \geq I - A \\ P_H^B(R - R_b^B - R_g^B) + (1 - P_H^B)\beta_g^C \geq I - A \\ P_H^B \cdot R_g^B + (1 - P_H^B)(1 - \beta_g)C - x \geq 0 \\ P_H^B \cdot R_g^B + (1 - P_H^B)(1 - \beta_g)C - x \geq P_L^B \cdot R_g^B + (1 - P_L^B)(1 - \beta_g)C \\ R = R_1^B + R_b^B + R_g^B. \end{cases} \tag{21.6}$$

According to Eq. (21.5), we get $(c_0, \tilde{c})$; and according to inequalities (21.6), we get $(c, \tilde{c}_0)$. It seems that we can get $(c_0, \tilde{c}_0)$ now, while, since we take the industry lending in, $(c_0, \tilde{c}_0)$ may no longer satisfy inequalities (21.5) and (21.6) at the same time. That means $(c_0, \tilde{c}_0)$ may no longer satisfy the principles of incentive compatibility.

Now, do not consider whether $(c_0, \tilde{c}_0)$ is correct or not. By using the following method, we can draw the specific values for R_1^G, R_b^G, R_g^G, R_1^B, R_b^B and R_g^B. We substitute the specific values into inequalities (21.5) and (21.6) for authentication, so we will know whether they are correct or not.

In order to obtain low information density optimal for loans under selective contracts, based on Eqs. (21.3) and (21.4), Tirole [7] also verified the following proposition:

If $\tilde{c}^S I$ is the contract's solution for the bad loan company when there is no adverse selection, the bad loan company meets the following plan:

$$\max_{\{\tilde{c}\}} \tilde{U}_b(\tilde{c}) \quad \text{s.t. } \tilde{U}_1(\tilde{C}) \geq 0. \tag{21.7}$$

Assume that when the good one use $\tilde{c}^{SI}$, $U_1(\tilde{c}^{SI}) \geq 0$ is still reasonable. (This assume called weak monotonic profit assumption).

When the good one choose c^*, and the bad one choose $\tilde{c}^{SI}$, if bank meets the participation constraint as an investor and bad one prefers $\tilde{c}^{SI}$ than c^*, then c^* maximize revenue for good one. Modeling:

$$\max_{\{\tilde{c}\}} U_b(c)$$
$$\text{s.t.} \begin{cases} U_1(C) \geq 0 \\ \tilde{U}_b(c) \leq \tilde{U}_b(\tilde{c}^{SI}). \end{cases} \tag{21.8}$$

The above configuration is called the separation configuration.

Tirole [7] proved that when satisfying the condition of weak monotonic profit assumption, separation configuration is the best low information density.

In the case of industry lending, Eqs. (21.1) and (21.8) need to join the participation constraint and the supervision constraint for guarantees. Modeling:

$$\max_{\{\tilde{c}\}} \tilde{U}_b(\tilde{c})$$
$$\text{s.t.} \begin{cases} P_H^B(R - R_b^B - R_g^B) + (1 - P_H^B)\beta_g^C \geq I - A \\ P_H^B \cdot R_g^B + (1 - P_H^B)(1 - \beta_g)C - x \geq 0 \\ P_H^B \cdot R_g^B + (1 - P_H^B)(1 - \beta_g)C - x \geq P_L^B \cdot R_g^B + (1 - P_L^B)(1 - \beta_g)C \\ R = R_1^B + R_b^B + R_g^B \end{cases} \tag{21.9}$$

and

$$\max_{\{c\}} U_b(c)$$
$$\text{s.t.} \begin{cases} R_H^G(R - R_b^G - R_g^G) + (1 - P_H^G)\beta_g^C \geq I - A \\ P_H^B \cdot R_b^G \leq P_H^B \cdot R + (1 - P_H^B)C - (I - A) - P_H^B[\frac{x}{\triangle p^B} + (1 - \beta_g)C] \\ -(1 - P_H^B)(1 - \beta_g)C \\ P_H^G \cdot R_g^G + (1 - P_H^G)(1 - \beta_g)C - x \geq 0 \\ P_H^G \cdot R_g^G + (1 - P_H^G)(1 - \beta_g)C - x \geq P_L^G \cdot R_g^G + (1 - P_L^G)(1 - \beta_g)C \\ R = R_1^G + R_b^G + R_g^G. \end{cases} \tag{21.10}$$

21.4.3 Specific Figures

If bank knows the type of loans, then both of them will get money under the industry lending.

$$U_1(c^{SI}) = P_H^G(R - R_b^G - R_g^G) + (1 - P_H^G)\beta_g^C - (I - A) \geq 0, \tag{21.11}$$

$$\tilde{U}_1(\tilde{c}^{SI}) = P_H^B(R - R_b^B - R_g^B) + (1 - P_H^B)\beta_g^C - (I - A) \geq 0. \tag{21.12}$$

Then we can see:

$$U_1(\tilde{c}^{SI}) = P_H^G(R - R_b^B - R_g^B) + (1 - P_H^G)\beta_g^C - (I - A),$$
$$\geq (P_H^G - P_H^B)(R - R_b^B - R_g^B - \beta_g C). \quad (21.13)$$

When the project is success, bank's income is $R_1^B = R - R_b^B - R_g^B$; when the project fail, bank's income is $\beta_g C$. Obviously, $R_1^B \geq \beta_g C$, otherwise, bank prefers to fail, it does not to be true.

Because $U_1(\tilde{c}^{SI}) \geq 0$, the condition of weak monotonic profit assumption is satisfying.

When the loans due diligence, we can see that $P_H^G > P_H^B$, However, if both of the loans choose to shirk, then it can be considered that at this time the probability of success are same, which means P_L^G and P_L^B are same. So $\triangle P^G > \triangle P^B$.

Under industry lending, expand separation configuration for good one. Modeling:

$$\max_{\{R_1^G, R_b^G, R_g^G\}} P_H^G \cdot R_b^G - A$$
$$\text{s.t.} \begin{cases} P_H^G(R - R_b^G - R_g^G) + (1 - P_H^G)\beta_g^C \geq I - A \\ P_H^B \cdot R_g^G \leq P_H^B \cdot R + (1 - P_H^B)C - (I - A) - P_H^B[\frac{x}{\triangle p^B} + (1 - \beta_g)C] \\ -(1 - P_H^B)(1 - \beta_g)C \\ P_H^G \cdot R_g^G + (1 - P_H^G)(1 - \beta_g^C) - x \geq 0 \\ P_H^G \cdot R_g^G + (1 - P_H^G)(1 - \beta_g)C - x \geq P_L^G \cdot R_g^G + (1 - P_L^G)(1 - \beta_g)C \\ R = R_1^G + R_b^G + R_g^G. \end{cases} \quad (21.14)$$

According to inequality (21.14), we get: $R_b^G \leq R - \frac{x}{\triangle p^B} - C - \frac{(I-A)-(\beta_g C)}{(P_H^B)}$; take calculated equals for (21.14), get the result $R_g^G = \frac{x}{\triangle p^G} + (1 - \beta_g)$, according to inequality (21.14), we get:

$$R_b^G \leq R - \frac{x}{\triangle p^G} - C - \frac{(I - A) - \beta_g C}{P_H^G}.$$

Since $\triangle P_G > \triangle P_B$, so

$$R - \frac{x}{\triangle p^B} - C - \frac{(I - A) - \beta_g C)}{P_H^B} < R - \frac{x}{\triangle p^G} - C - \frac{(I - A) - \beta_g C}{P_H^G}.$$

We can get the results:

$$R_{b_{\max}}^G = R - \frac{x}{\triangle p^B} - C - \frac{(I - A) - \beta_g C}{P_H^B}, \quad (21.15)$$
$$R_1^G = \frac{x}{\triangle p^B} - \frac{x}{\triangle p^G} + \beta_g C + \frac{(I - A) - \beta_g C}{P_H^B} + \beta_g C. \quad (21.16)$$

The terms of the contract c contains are as follows: When the project success, bank can gain $R_1^G = \frac{x}{\triangle p^B} - \frac{x}{\triangle p^G} + \beta_g C + \frac{(I-A)-\beta_g C}{P_H^B}$, loans can gain $R_b^G = R - \frac{x}{\triangle p^B} - C - \frac{(I-A)-\beta_g C}{P_H^B}$, guarantees can gain $R_g^G = \frac{x}{\triangle p^G} + (1-\beta_g)C$. Modeling for the bad one:

$$\max_{\{R_1^B, R_b^B, R_g^B\}} P_H^B \cdot R_b^B - A$$
$$\text{s.t.} \begin{cases} P_H^B(R - R_b^B - R_g^B) + (1 - P_H^B)\beta_g^C \geq I - A \\ P_H^B \cdot R_g^B + (1 - P_H^B)(1 - \beta_g^C) - x \geq 0 \\ P_H^B \cdot R_g^B + (1 - P_H^B)(1 - \beta_g)C - x \geq P_L^B \cdot R_g^B + (1 - P_L^B)(1 - \beta_g)C \\ R = R_1^B + R_b^B + R_g^B. \end{cases} \tag{21.17}$$

Take calculated equals for (21.17), get the result $R_g^B = \frac{x}{\triangle p^B} + (1-\beta_g)C$, according to inequality (21.17) we get: $R_b^B \leq R - \frac{x}{\triangle p^B} - C - \frac{(I-A)-\beta_g C}{P_H^B}$. So we can get the results:

$$R_{b_{\max}}^B = R - \frac{x}{\triangle p^B} - C - \frac{(I - A) - \beta_g C}{P_H^B}, R_1^B = \frac{(I - A) - \beta_g C}{P_H^B} + \beta_g C. \tag{21.18}$$

The terms of the contract $\tilde{c}$ contains are as follows:

When the project success, bank can gain $R_1^B = \frac{(I-A)-\beta_g C}{P_H^B} + \beta_g C$, loans can gain $R_b^B = R - \frac{x}{\triangle p^B} - C - \frac{(I-A)-\beta_g C}{P_H^B}$, guarantees can gain $R_g^B = \frac{x}{\triangle p^B} + (1 - \beta_g)C$.

21.4.4 Verify for Results

Take the six data obtained from the Sect. 21.4.3 in inequalities (21.5) and (21.6), we can see that inequalities (21.5) and (21.6) are established. The six data satisfies the incentive compatible and the individually profitable, mean while maximizes revenue for loans.

21.4.5 Analysis

In the Sect. 21.4.3, since

$$R - \frac{x}{\triangle p^B} - C - \frac{(I - A) - \beta_g C}{P_H^B} < R - \frac{x}{\triangle p^G} - C - \frac{(I - A) - \beta_g C}{P_H^G},$$

then $R_{b_{\max}}^{G} = R - \frac{x}{\triangle p^{B}} - C - \frac{(I-A)-\beta_g C}{P_H^B}$. In fact, $R - \frac{x}{\triangle p^{G}} - C - \frac{(I-A)-\beta_g C}{P_H^G}$ is the revenue for good loans when there is no adverse selection under the industry lending. We can find that if the type of the loans is private information, then there will be a downward distortion for good loans, the earnings that good one can gain in the success of the project will reduce. Guarantees income constants and bank earnings increases.

In the case of selective contracts under industry lending, no matter what type of the loans is, guarantees play a supervisory role, making the loans chooses to due diligence. Since average revenue for guarantees is always greater than 0, the guarantees will be happy to participate. Bank will also agree to participate because it is a profitable loan no matter what type of the loans bank faced. According to $(c, \tilde{c})$, good loans can be separate from bad one. Bad one would like to choose $\tilde{c}$ rather than c. Good loans can make their guaranteed revenue maximize, overcome the effects of adverse selection for them.

21.5 Conclusion

Compare with traditional design for loan agreements, the future design for loan contracts can make the one who has more information (loans) as a contract designer, and the one who has less information (bank) as a recipient of the contract. By designing selective contract, bad SMEs unintentionally imitate to be good SMEs, so good SMEs can get loans successfully, and maximize their guaranteed income.

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Chapter 22
The Identification of Recessive Community Organization in Group Decision Making

Chunxiang Guo, Ruili Shi and Zhiyong Zhou

Abstract The reality of group decision problem is often a complex large group problem, and because of the influence of the factors such as personality, psychology, values and connection degree, group members can form different community organizations. The structure of community organizations, especially the division of the recessive community organizations and its structure in the group has a significant influence on the decision results. In this paper, under the perspective of complex network, the relationship between members of the group decision was abstracted as the weighted network, applying the agglomerative algorithm idea of nodes similarity, using the theory and method of the community partition of complex network, a community partition algorithm for the node empower network based on the measure the similarity of nodes is designed and verified. The algorithm considers both the properties and structural characteristics of nodes in the network, respectively reflects the individual's knowledge level and communication network in group decision-making, which can be used to search for the recessive organization of group decision-making, laid a foundation to simulate group evolution process and the decision results.

Keywords Decision group · Opinion evolution · Complex network · Community structure

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_22,

22.1 Introduction

Group decision has become the mainstream decision method in today's society for high accuracy rate and low risk with complicated modern management task and specialized decision process [2, 4, 7]. It has extensive significance and application background in politics, economy, military, industrial process and engineering system [3]. Problems in group decision, becoming increasingly complex, have presented new features with the complicated and variable decision environment and tasks. Firstly, the update of individual view in decision is affected by other individuals in surroundings (or the selecting trend of social group) due to large-scale decision group; Secondly, with increased variability, the individuals in group decision have dynamic or even recessive preferences, so their views dynamically evolve; Thirdly, the complicated relationships between the groups have community structure and network evolution; In addition, there are conflicts in group decision to different degrees [5, 6, 11, 13, 22, 24]. Consequently, the realistic problems of group decision often concern complex and large groups. Thus a large-scale and complex network between decision members is formed based on interpersonal relationship. And the communication and range of social activities among decision members are different on account of factors such as degree of relation, personality, psychology and values. The people who are intimate and share values or interests usually form their own social circle-group. According to the base of the formation, groups can be divided into dominant and recessive groups. In university campus, for example, dominant groups are formed based on official organizational relationships such as university colleges, professionals and classes. In addition to the division of groups based on tangible organizations, there are spontaneous and informal organizations formed due to interests, hobbies and personality-recessive groups.

Dominant and recessive groups are general structures in social activities. As long as interpersonal relationships exist, there will be a division of groups. And decision group is, of course, no exception. The effect of dominant organizations on decision in decision group has attracted the attention of scholars. But it's noteworthy that whether the existence of internal recessive organizations can influence the evolution of decision view, behavior of a complex group decision support system or decision results. The first step for studying the evolution law of group decision with internal organizations is to solve the excavation of the internal recessive organizations in groups, determining a reasonable division of groups.

The recessive organizations in decision group were studied on the perspective of complex networks, abstracting the membership of decision group into interpersonal networks in complex network. A node-weighted network was established according to the individual attributes of decision group. Based on the theory and method of community partition in complex networks, the community partition algorithm in a node-weighted network was proposed by using agglomerative algorithm of node similarity. The mentioned community groups, unless indicated, refers specifically to the spontaneous and informal community organizations formed due to differences in attributes.

22.2 Community Partition Algorithm Based on Node Similarity

The community nature of realistic networks, once proposed, has acquired widespread concern in the academic community. Many scholars have done plentiful researches on excavating the community structure of network. Currently, the community partition of un-weighted networks has obtained excellent results. Leicht et al. [10] proposed the calculation of node similarity by using the ratio of expected numbers between common neighbors. When exploring the solution of node similarity, Pan et al. [20] put forward the community partition algorithm of node similarity in un-weighted networks. The algorithm achieves good effects in the community partition of un-weighted networks. Except the methods of node similarity, Newman [15, 16] early put forward the hierarchical clustering algorithm for community partition. Reflecting a multi-level structure of networks, the clustering technology has been applied in social and biological networks. Newman applied the greedy algorithm to community partition in order to improve the efficiency of structural division in large networks. A fast algorithm for community partition was proposed, greatly meliorating the complexity. Many scholars have studied the partitioning methods of community nodes based on the concept of betweenness. Newman [17] proposed the module functions for evaluating the effect of community partition based on the typical GN algorithm. Thus the effect of community partition can be analyzed through solving the module functions, finding the optimal partition.

Subsequently, the concept of modularity matrix was put forward by Newman based on further studies on module functions [18, 19]. The optimal community partition can be obtained through solving module function and modularity matrix. Zhang [27], Newman et al. [14] focused on the abnormally dense network structure of node connection. Using random matrix theory, they identified the community structure through the map of networks. Newman [9] searched for the significance of community structure by measuring robustness of network structure. Furthermore, Tsuchiura et al. [21] introduced the concept of Brown particles to measure the "distance" between two network nodes, proposing a method for community partition through information centrality.

The above methods have achieved excellent results in community partition of un-weighted networks. However, there will be a large deviation when many classical algorithms are applied to partition weighted networks. Although literature [17, 20] promoted the concept of module functions to weighted networks, the algorithm is very complex with low computational efficiency. Thus the community partition for weighted networks requires further researches. The effects of weight on structural property should be taken into account in the community partition for weighted networks. And the community partition obtains new features when introducing the attribute values of nodes.

We abstracted the interpersonal network of group decision into weighted network: decision individuals into network nodes, and their relationships into the edges of the nodes. And the weight of edge was set in terms of the closeness of individual connection. Combined with the node-weighted network based on group decision, the agglomerative algorithm of node similarity was used to improve the measurement algorithm of node similarity. And a new community partition algorithm was put forward to identify the recessive organizations in decision group.

22.2.1 Background Knowledge

Here is the relevant basic knowledge.

1. Node degree [21]
   The model of directed weighted complex network is represented by G, $G = \{V, E\}$. $V = \{v_1, v_2, \cdots, v_n\}$ is a collection of nodes, and $E = \{e_1, e_2, \cdots, e_m\} \in V \times V$ is a collection of edges. The number of network nodes is $n = |V|$, and the number of edges is $m = |E|$. $v_i \in V(i = 1, 2, \cdots, n)$ represents every node in the network. $(v_i, v_j) \in E$ represents a directed edge from node v_i to node v_j. For a network $G(V, E)$, w_{ij} is the weight of edge e_{ij}. If there is no edge between node v_i and node v_j, $w_{ij} = 0$. The degree of node v_i is defined as the weights of the edges with the connected nodes, specifically expressed as: $w(i) = \sum_{v_j \in V} w_{ij}$.
2. Common neighbor [22]
   Two nodes v_i and v_j are randomly selected. If there is an edge between v_i and v_j, v_i and v_j are neighbor nodes. Then v_z, the node except v_i and v_j, was randomly selected. If both v_i and v_j have a direct edge connected with v_z, v_z is the common neighbor for v_i and v_j.
3. Node-weighted network
   Let $W = [w_{ij}]$ be the adjacency matrix of weighted graph G, where $w_{ij} \in [0, \pm x)$ is the weight of the edge between node v_i and v_j. Based on weighted graph G, if every node has s object attributes, the weight of node v_i is $c_i = (c_{i1}, c_{i2}, \cdots, c_{is})$, representing the level of the node's object attributes–the weight of the node. And G is the node-weighted network.

22.2.2 Distances Between Attribute Features of Nodes

Eigenvector centrality [27] is an important indicator to assess the significance of network nodes, describing the characteristics of the node. If there are n nodes in the network: $v_1, v_2, \cdots, v_n$, every node has m attribute features, and the m attribute features of the $No.i$ node are set as $x_{i1}, x_{i2}, \cdots, x_{im}$. d'_{ij}, the distance of attribute between node i and j, is defined as

$$d'_{ij} = \sqrt[q]{\sum_{k=1}^{m} \left| x_{ik} - x_{jk} \right|^q}, \quad i \in \{1, 2, \cdots, n\}, \quad j \in \{1, 2, \cdots, n\}, \tag{22.1}$$

where q is a positive integer and can be adjusted according to needs.

Node attributes reflect the characteristics of the node. And measuring the distance between two node attributes can reflect the similarity between the two nodes to a certain extent. In the community partition based on node similarity, the closer the distance of the two nodes' attribute features is, the higher their similarity will be. Thus they are more inclined to belong to the same community.

For the community structure in decision groups, the attributes that influence individual preferences, as mentioned earlier, are personality, psychological and intellectual level. And personality and psychological characteristics can be reflected by building interpersonal networks. Therefore, only the effect of intellectual level (the node attribute) on node similarity was taken into consideration. Let the intellectual level $\varphi_i \in [1, 9]$, $d^{'}_{ij} = |\varphi_i - \varphi_j|$.

The maximum minimum method was adopted to standardized process the difference of intellectual levels. Thus the degree of distance between the two nodes' intellectual levels can be better reflected. And $P_{d^{'}_{ij}}$ represents the degree of difference between the intellectual levels of node i and j:

$$P_{d^{'}_{ij}} = \frac{\max(d') - d^{'}_{ij}}{\max(d') - \min(d')}, \tag{22.2}$$

where $\max(d'), \min(d')$ is respectively the maximum and minimum of the differences in intellectual level between all the nodes in network G. The value range of $P_{d^{'}_{ij}}$ is [0, 1]. And the more the difference between the two nodes' intellectual levels is the smaller the value of $P_{d^{'}_{ij}}$ will be.

22.2.3 Node Similarity Matrix

Node similarity is a degree of similarity between nodes in aspects such as network structure and attribute features, which is the basis for dividing community. The larger the similarity is, the greater the possibility that the two nodes belong to the same community will be. Node similarity can be considered from the following three aspects:

First, based on the similarity of network relational structure, node similarity can be portrayed via the concept of common neighbor. For z (the common neighbor of node i and j), if i and j have a closer relationship with z, they are more important in the relational network of z, which means there is a larger similarity between i and j. For example, if node z has no connection with other nodes except for node i and j, the contribution value of z for the similarity between i and j is 1; If z is also the neighbor node of k, the contribution value of z for the similarity between i and j is 2/3. In a weighted network, the contribution value of the common neighbor for the similarity between i and j is related to not only the number of z neighbors of but also the weight ratio of i and j in all the neighbors of z. The larger the weight ratio of i and j in all the neighbors of the common neighbor z, the greater similarity between i and j presented by z will be. Thus every node in the node collection of the common neighbors of node i and j can embody the similarity between i and j, and the similarity is proportional to the weights of i and j in all the neighbors of the node and inversely proportional to the node's degree.

Second, except the similarity in the relational structure of nodes, the similarity of node attributes is also an important measurement for node similarity. In a node-weighted network, differences between node attributes largely determine node similarity. The larger the difference between node attributes is, the smaller the node similarity will be. $P_{d'_{ij}}$ was used to describe the similarity between two node attributes.

The final aspect is the connectivity between nodes. The shortest distance between two nodes reflects their similarity from the perspective of betweenness centrality: the larger the shortest distance between two nodes is, the more remote their relationship will be, and vice versa. The relationship between two nodes is closest when they are directly connected. Besides, the weight reflects the connection between nodes: the larger the weight of nodes is, the closer the relationship will be. Therefore, node similarity can be described from the perspective of the shortest distance between nodes and the weight on the shortest path, which is defined as follows:

$$w_{d_{ij}} = \frac{\min(w(i, j))}{d_{ij}}. \tag{22.3}$$

In Eq. (22.3), $w(i, j)$ is the collection of weights of the edges on the shortest path from node i to j, and d_{ij} is the norm of the shortest path from node i to j [23].

The node similarity matrix can be defined as follows based on the above ideas:

$$S_{ij} = \begin{cases} P_{d'_{ij}} w_{d_{ij}} + \sum_{z\in\Gamma(i)\cap\Gamma(j)} \frac{w_{iz}+w_{jz}}{w(z)}, & i \text{ and } j \text{ are connected} \\ 0, & \text{otherwise,} \end{cases} \tag{22.4}$$

where $\Gamma(i)$ represents the collection of the neighbor nodes of node i, and $\Gamma(i)\cap\Gamma(j)$ is the collection of the common neighbors of node i and j. $P_{d'_{ij}}$ is given by Eq. (22.2), and $P_{d'_{ij}} \in [0, 1]$. Particularly, to avoid ignoring the similarity between the two nodes with the largest difference in knowledge level (namely when $P_{d'_{ij}} = 0$, $S_{ij} = 0$), the calculation of similarity matrix, such as $P_{d'_{ij}} = 0$, is replaced by

$$P_{d'_{ij}} = \frac{(\max(d') - c\max(d'))}{2(\max(d') - \min(d'))},$$

where $c\max(d')$ is the difference of knowledge level that ranks only second to the maximum.

22.2.4 Description of Algorithm

The idea of agglomerative process was adopted to partition the community structure. According to Eq. (22.4), the similarity matrix with n order for network nodes $S = \left[s_{ij}\right]_{n \times n}$ was obtained. And the node pairs with the greatest value of similarity in the network were gradually found to finally achieve community partition. Specific algorithms are shown as follows:

The community partition algorithm based on node similarity:

Step 1. The two nodes with the largest similarity $v_i, v_j \in V$ are found in node similarity matrix S, constituting the initial community: $g(1) = \{v_i, v_j\}$. And the node similarity $S(i, j) = 0$.

Step 2. Judge whether the sum of nodes in the existing communities is N. If it's N, community partition is over, and quit the algorithm; if it's less than N, update the node similarity matrix S. Find the maximum of similarities max. If max $= 0$, the community partition is over, and exit the algorithm. Otherwise, enter Step 3.

Step 3. The node pair with the node similarity that's equal to max $v_m, v_r \in V$ is found. If v_m and v_r don't belong to any existing communities, a new community $g(k) = \{v_m, v_r\}$ is formed; if one of v_m and v_r belong to the existing community g, the other one is put into community g; if both v_m and v_r belong to different existing communities, judge whether the node similarity $S(m, r)$ is larger than threshold value ε. If yes, combine the two communities of v_m and v_r. If not, enter Step 4.

Step 4. Repeat Step 2 and 3 until the end of the network partition, and exit the algorithm.

The threshold value of similarity can be used for adjusting the number of community partition to accomplish better results in this algorithm. Specifically, different networks should be set with different threshold values of similarity based on the size of node similarity and practical needs to achieve a reasonable effect of network partition.

22.2.5 Effectiveness Analysis of Algorithm

The proposed algorithm was used to conduct community partition on the classical complex network-Zachary karate club network [26] to illustrate the effectiveness of the algorithm. The network is a graph of social relations obtained through Zachary's two-year observation on the group relation of a karate club in a university of the United States. During the observation, Zachary found that the club director has a disagreement with the principal of the university due to certain reasons. Consequently, the community members were divided into small communities that respectively centered on the president and the manager.

The club network given by Zachary [26] is an unweighted network without node weight. Therefore, variables such as node weight and connection weight should be removed when utilizing the community partition algorithm of node similarity. In

Table 22.1 Maximum similarity nodes in a karate club network

Node	MSN	Node	MSN	Node	MSN
1	2	13	2, 14	25	24
2	1	14	1	26	28
3	34	15	8, 15, 21, 23, 24, 30, 31, 32	27	30, 33
4	1	16	34	28	26, 34
5	6	17	1	29	34
6	5	18	3, 4, 8, 14, 20, 22	30	34
7	11	19	9, 15, 16, 21,23,24,30,31,32	31	33
8	14	20	14	32	34
9	33	21	9, 15, 16, 19, 23, 24, 30, 31, 32	33	34
10	1, 2, 8, 9, 14, 28, 29, 31, 33	22	3, 4, 8, 14, 18, 20	34	33
11	7	23	9, 15, 16, 19, 21, 24, 30, 31, 32		
12	2, 3, 4, 5, 6, 7, 8, 9, 11, 13, 14, 18, 20, 22, 32	24	3, 34		

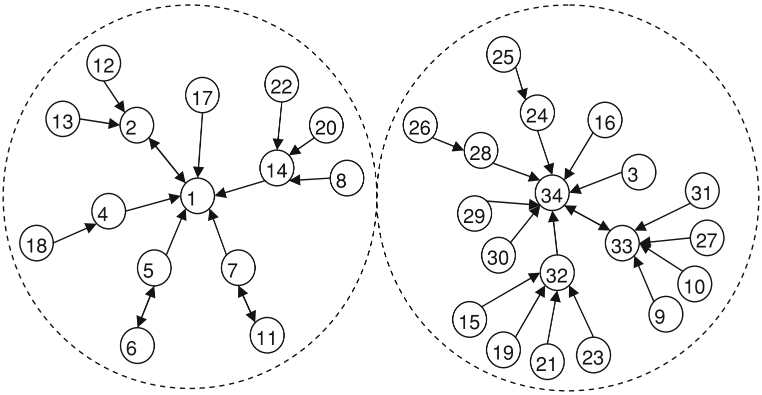

Fig. 22.1 Karate community partition without considering individual attributes

this case, the algorithm degrades into a community partition algorithm for general unweigthed networks. The maximum likelihood nodes for the nodes around this club network were obtained via the algorithm, shown in Table 22.1.

The partition through the algorithm was shown in Fig. 22.1 when the threshold value of similarity for community combination $\varepsilon = 2$. Node 1 and 34, respectively, represent the club director and the principal, and the arrow points to the maximum similarity node of one node. Figure 22.1 shows that node 1 and 34 are respectively the core nodes of the two communities. The community of the club director (node 1) was taken as the example. Members of the community were mostly closely linked with the director or related with the director via other members, gathering together as a community due to the function of the club director. The results are consistent with the practical observations of Zachary.

Table 22.2 Relational matrix of a weighted network and node weights

Node	1	2	3	4	5	6	7	8	9	1	11	12	13	14	15	16	17	18	19	20
1	0	7	0	0	0	0	0	0	0	0	1	0	0	6	0	0	0	0	0	0
2	7	0	5	5	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0
3	0	5	0	0	3	0	0	2	0	0	0	0	1	0	4	0	0	0	7	0
4	0	5	0	0	0	0	4	0	0	0	3	0	0	4	0	0	0	0	2	3
5	0	0	3	0	0	0	0	2	0	0	0	0	8	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	3	1	0	3	0	0	0	6	0	0	0	0	0
7	0	0	0	4	0	0	0	2	0	4	0	4	0	0	0	0	0	0	0	6
8	0	0	2	0	2	3	2	0	0	0	0	0	0	0	0	6	0	4	0	0
9	0	0	0	0	0	1	0	0	0	0	5	0	0	0	0	0	0	0	6	0
1	0	0	0	0	0	0	4	0	0	0	0	3	0	2	0	0	3	6	0	0
11	1	0	0	3	0	3	0	0	5	0	0	0	0	0	8	0	0	0	0	0
12	0	0	0	0	0	0	4	0	0	3	0	0	0	0	0	0	0	3	0	0
13	0	0	1	0	8	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0
14	6	2	0	4	0	0	0	0	0	2	0	0	0	0	0	7	0	0	0	0
15	0	0	4	0	0	6	0	0	0	0	8	0	0	0	0	0	4	2	0	0
16	0	0	0	0	0	0	1	6	0	0	0	0	0	7	0	0	1	0	3	0
17	0	0	0	0	0	0	0	0	0	3	0	0	5	0	4	1	0	3	0	0
18	0	0	0	0	0	0	0	4	0	6	0	3	0	0	2	0	3	0	0	0
19	0	0	7	2	0	0	0	0	6	0	0	0	0	0	0	3	0	0	0	6
20	0	0	0	3	0	0	6	0	0	0	0	0	0	0	0	0	0	0	6	0
Node weight	2	7	6	4	4	3	8	5	7	2	3	4	8	6	4	5	1	6	2	7

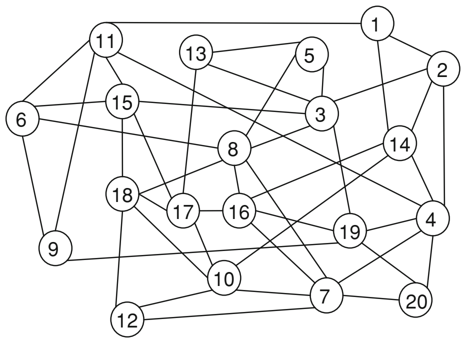

Fig. 22.2 Network relationship

22.3 Numerical Examples and Result Analysis

A small weighted network was taken as an example for community partition. The weight of each node and edge were shown in Table 22.2, and the network relationship in Fig. 22.2.

First, the node similarity matrix can be calculated according to Eq. (22.4). The maximum similarity neighbor of each node was shown in Fig. 22.3. Based on the

Table 22.3 Maximum similarity neighbors (MSN) of nodes in a weighted network

Node	MSN	Node	MSN	Node	MSN	Node	MSN	Node	MSN
1	4	5	13	9	11	13	5	17	10
2	3	6	15	10	18	14	16	18	10
3	2	7	20	11	15	15	11	19	3
4	14	8	16	12	10	16	8	20	7

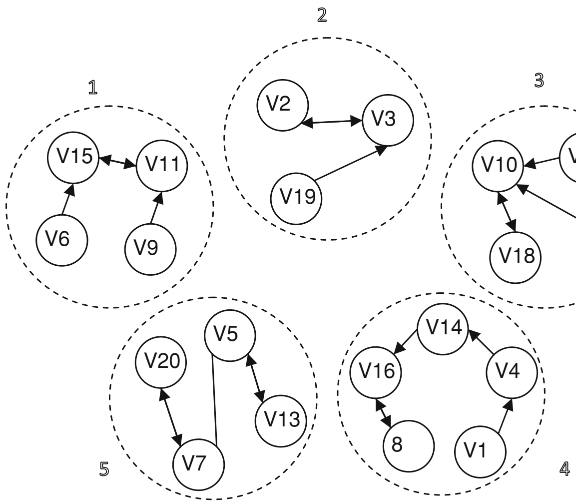

Fig. 22.3 Results of group partition based on weighted networks

steps of community partition, the results of partition were shown in Fig. 22.3 when the threshold value of similarity for community combination $\varepsilon = 3$.

The result of utilizing the proposed algorithm for community partition was shown in Fig. 22.3, and the arrow points to the maximum similarity nodes. Different partitions can be obtained through adjusting the threshold value of similarity for community combination. Comprehensive analysis found that the partition of community structure conforms to features of location and relation of network nodes. And the level of knowledge also plays a certain role in the partition. The results show that the closer nodes that share more connections were divided into the same network; Nodes tend to be combined to the nodes with lower difference in knowledge level to constitute a community. The partition fitting the expectation further confirmed the effectiveness of the algorithm.

The algorithm can solve the network problem that multiple neighbor nodes with the same similarity can't be reasonably partitioned in previous algorithms. In addition, it can also ensure both the node and its maximum similarity node belong to one community. Furthermore, the situation that two nodes with a large similarity are not assigned to the same community can be avoided. Thus a more scientific and accurate community partition can be assured. Meanwhile, the individual attribute, characteristics of relational network and individual knowledge level of a decision group were considered in this algorithm based on abstracting the interpersonal network in decision groups. Thus the algorithm is suitable for identifying and classifying recessive communities in group decision. And the results have important theoretical and practical significance for studying the results of decision activities and behaviors.

22.4 Conclusions

The realistic problems of decision often concern complex and large groups. And the group members differ in ways of communication and scope of social activities due to degree of relation, personality, knowledge and values, constituting different communities. The organizational structure of communities, especially the existence and structure of recessive organizations in a group, undoubtedly have a significant impact on the results of decision. Based on the large-scale complex network formed by the interpersonal network among decision members, the social network in group decision was abstracted into a node-weighted network. Thus the community partition algorithm for node-weighted networks was proposed based on the features of node-weighted networks and agglomerative algorithm in community partition. The algorithm considers node attributes and similarity of characteristics in node structure, respectively reflecting the knowledge level of decision individuals and the social network in group decision. Used to identify the recessive organizational structure in a group, the algorithm improves the accuracy to a certain degree and reduces time complexity. Consequently, the foundation of simulating the evolution and results of opinions in group decision was laid.

However, only psychology, personality and knowledge level were taken into account in the attributes that affect individual preference, and only knowledge level in node attributes that influence node similarity was considered. In fact, many factors, such as personal values and customs, will affect the behavior of individual decision on account of complex and variable individual attributes. Thus multidimensional node attributes should be emphasized in future studies.

Acknowledgments This work was partly supported by the National Natural Science Funds of China (Project No. 71071102), and the Fundamental Research Funds for the Central Universities (No. skqy201324).

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Chapter 23
A Superiority Index Based Method for MCDM Under Uncertain Linguistic Setting

Zhibin Wu

Abstract This paper proposes a method to aid the selection process of multi-criteria decision making (MCDM) problem, in which the criteria values provided by experts are in the form of uncertain linguistic variables. Based on the partial order of uncertain linguistic variables, the superiority index of one alternative over another for a given criterion and the overall superiority index of one alternative are defined. Some properties of the superiority index are presented and discussed. Then a procedure based on the superiority indices is presented to select the best alternative(s). The proposed method is also extended to multi-criteria group decision making. Finally, one example of evaluating the technological innovation capability of enterprises is given to verify the proposed method.

Keywords Multi-criteria decision making (MCDM) · Superiority index · Linguistic variable · Group decision making

23.1 Introduction

Multi-criteria decision making (MCDM) addresses the problem of choosing an optimum choice from a set of alternatives associated with non-commensurate and conflicting attributes [7]. MCDM problems arise in many practical situations and have drawn much attention in the management and engineering field. A lot of methods for solving such problems have been proposed under numerical settings, for example, simple additive weighting, multiplicative exponential weighting, the entropy method and technique for order preference by similarity to ideal solution (TOPSIS) [7].

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_23, © Springer-Verlag Berlin Heidelberg 2014

There are cases in which the information cannot be expressed precisely in a quantitative form but may be stated only in linguistic terms. For example, when attempting to qualify phenomena related to human perception, we are likely to use words in natural language instead of numerical values. (e.g. when evaluating the "comfort" or "design" of a car, terms like "bad", "poor", "tolerable", "average", or "good" can be used [9]). A more realistic measurement is to use linguistic assessments instead of numerical values [11, 12]. Linguistic variables are very useful in situations where the decision making problems are too complex or ill-defined to be described properly using conventional quantitative expressions.

A number of studies have emphasized the impotence of MCDM with fuzzy or linguistic data [8]. Fuzzy or linguistic MCDM approaches have been applied to many areas, for example, technology transfer strategy selection [2], product design and selection [10], alternative-fuel buses selection [19], collaboration satisfaction evaluation [5], supplier evaluation [13]. Furthermore, some methods of MCDM under linguistic environment have been proposed [6, 14–17]. Xu [15] presented uncertain linguistic ordered weighted averaging (ULOWA) operator and uncertain linguistic hybrid aggregation (ULHA) operator to solve MCDM with uncertain linguistic information. Wu and Chen [14] developed a method named the maximizing deviation method to determine the optimal relative weights of attributes in multiple attribute group decision making with linguistic variables. Xu [16] designed an optimization model based on the ideal point of attribute values to determine the attribute weights with some incomplete weight information. Xu and Da [17] also proposed an optimization model based on the deviation degree and ideal point of uncertain linguistic variables to derive the attribute weights. Fan and Liu [6] provided a method to solve the group decision making problem with multi-granularity uncertain linguistic information. In the method, multi-granularity uncertain linguistic information is transformed into trapezoidal fuzzy numbers and an extension of TOPSIS is conducted to rank the alternatives.

Previous studies have supplied interesting results and have made significantly advancement to MCDM analysis under fuzzy or linguistic environment. However, the methods for MCDM with linguistic information mentioned above mostly focused on deriving the attribute weights. The order relations inherent in the preference information of decision makers are seldom addressed. Inspired by the methods dealing with ordinal data in numerical setting [3], we propose a superiority index based method for MCDM problems under uncertain linguistic setting utilizing the order information of the given attribute values.

The rest of the paper is organized as follows. Section 23.2 introduces the concept of linguistic variable and describes the MCDM problem. Section 23.3 firstly defines the superiority indices of alternatives and then discusses some properties of the superiority index. A procedure based on the superiority indices is also presented to select the best alternative(s). Section 23.4 generalizes the given method to group decision making and other cases. Section 23.5 gives an example to illustrate the proposed method and Sect. 23.6 concludes the paper.

23.2 Preliminaries and Problem Description

For the convenience of analysis, this section introduces some definitions of uncertain linguistic variables. These basic definitions and notations will be used throughout the paper, unless stated otherwise.

The basic ideas of definitions and characteristics for linguistic variable can be found in [15–17]. Suppose that $S = \{s_\alpha | \alpha = -t, \cdots, -1, 0, 1, \cdots, t\}$ is a finite and totally ordered discrete term set whose cardinality value is an odd one, such as 7 and 9, where s_α represents a possible value for a linguistic variable. The semantics of linguistic variables is usually represented by fuzzy numbers. To preserve all the information, the discrete linguistic label set S is extended to a continuous linguistic label set $\bar{S} = \{s_\alpha | s_{-q} \leq s_\alpha \leq s_q,\ \alpha \in [0, q]\}$, where q $(q > t)$ is a sufficiently large positive integer.

Definition 23.1 [15] Let $\tilde{s} = [s_\alpha, s_\beta]$, where $s_\alpha, s_\beta \in \overline{S}$, s_α and s_β are the lower and upper limits, respectively, then $\tilde{s}$ is called an uncertain linguistic variable.

The MCDM problem with uncertain linguistic variables refers to the problem of selection or ranking alternatives that are associated with incommensurate and conflicting attributes, in which the attribute values take the form of uncertain linguistic variables. The following notations are used to present the problem.

Let $M = \{1, 2, \cdots, m\}$, $N = \{1, 2, \cdots, n\}$. Suppose there are $n (n \geq 2)$ potential alternatives denoted by $X = \{X_1, X_2, \cdots, X_n\}$. Each alternative is evaluated with respect to a predefined attribute set $C = \{C_1, C_2, \cdots, C_m\}$. The performance values of each alternative under each alternative constitute a decision matrix denoted by $A = (A_i^j)_{n\times m}$, where $A_i^j = [LA_i^j, RA_i^j]$ is an uncertain linguistic variable in a linguistic term set for the alternative X_i with respect to the attribute C_j. Let $w = (w_1, w_2, \cdots, w_m)^T$ be the weight vector of attributes, such that $\sum_j^m w_j = 1, w_j \geq 0$, $j \in M$ and w_j denotes the weight of attribute C_j. The problem concerned in this paper is how to rank the alternatives or select the most desirable alternative(s) using the decision matrix A and vector w.

23.3 The Proposed Method

In this section, the concepts of superiority indices are given and some properties are analyzed. Then the proposed method is described as a decision procedure based on the superiority indices.

In order to define the superiority index between two alternatives, we introduce the order relation between uncertain linguistic variables A_i^j and A_k^j as follows: $A_i^j \preceq A_k^j$ if and only if $LA_i^j \leq LA_k^j$ and $RA_i^j \leq RA_k^j$; $A_i^j = A_k^j$ if and only if $LA_i^j = LA_k^j$ and $RA_i^j = RA_k^j$; $A_i^j \prec A_k^j$ if and only if $A_i^j \preceq A_k^j$ and $A_i^j \neq A_k^j$.

Note that the order given above is only a partial order. Therefore it is possible there are some pairs of uncertain linguistic variables which cannot be compared.

However, because of the easy computation and understanding, we first construct our theory on such order.

Definition 23.2 For every two alternatives X_i, X_k in $X$and a attribute C_j in C, denote

$$b_{ij}^{(k)} = \begin{cases} 1, & \text{if } A_i^j \prec A_k^j \\ \frac{1}{2}, & \text{if } A_i^j = A_k^j, \ 1 \le j \le m \\ 0, & \text{otherwise.} \end{cases} \tag{23.1}$$

Let $b_{ik} = \sum_{j=1}^{m} b_{ik}^{j}$, which is called the superiority index of X_i over X_k; Let $S_i = \sum_{k=1}^{n} b_{ik}$, which is called the superiority index of X_i, $i \in N$.

From the above definition, we can easily observe that the superiority indexes have the following properties: (1) $b_{ii}^{j} = \frac{1}{2}$, $j \in M$ and $b_{ii} = \frac{1}{2}m$; (2) $0 \le b_{ik} \le m$; (3) $\frac{1}{2}m \le S_i \le m(n-1) + \frac{1}{2}m$.

Definition 23.3 For every two alternatives X_i, X_k in X, for the attribute C_j, the different order relations between the two alternatives are defined as: (1) $X_i \leqq X_k$ if and only if $A_i^j \preceq A_k^j$, $\forall j \in M$; (2) $X_i \le X_k$ if and only if $A_i^j \preceq A_k^j$, $j \in M$, and $A_i^{j_0} \prec A_k^{j_0}$ for some j_0; (3) $X_i < X_k$ if and only if $A_i^j \prec A_k^j$, $\forall j \in M$.

With the order of alternatives, we introduce the following solution concepts.

Definition 23.4 Let X_e be an alternative in X. Then (1) X_e is an inferior alternative in X if $X_e \le X_i$ for some $X_i \in X$; (2) X_e is a non-inferior alternative in X if there is no $X_i \in X$ such that $X_e \le X_i$; (3) X_e is an optimal alternative in X if $X_i \leqq X_e$, for all $X_i \in X$; (4) X_e is a strongly optimal alternative in X if $X_i < X_e$ for all $X_i \in X$ $(i \ne e)$.

Lemma 23.1 *Let X_e and X_f be two alternatives in X. Then $X_e > X_f$ if and only if $b_{ef} = m$.*

Proof Suppose $X_e > X_f$. Then $A_f^j \prec A_e^j$, $\forall j \in M$ by Definition 23.3 (3). Hence $b_{ef}^j = 1$, $\forall j \in M$. Thus $b_{ef} = \sum_{j=1}^{m} b_{ef}^j = m$. Conversely, suppose that $b_{ef} = m = \sum_{j=1}^{m} b_{ef}^j$. Since $0 \le b_{ef}^j \le 1$, we have $b_{ef}^j = 1$ such that $A_f^j \prec A_e^j$ for each j by Definition 23.2. From Definition 23.3 (3), $X_e > X_f$. □

Lemma 23.2 *X_e is a strongly optimal alternative in X if and only if $S_e = m(n-1) + \frac{1}{2}m$.*

Proof Necessity. Suppose X_e is a strongly optimal alternative in X. Then $X_e > X_i$ and $b_{ei} = m$, for $i \ne e$ by Lemma 23.1. Since $b_{ee} = \frac{1}{2}m$, we have $S_e = \sum_{i=1}^{n} \sum_{j=1}^{m} b_{ei}^j = m(n-1) + \frac{1}{2}m$. Sufficiency. Suppose $S_e = m(n-1) + \frac{1}{2}m$. Since $0 \le b_{ef}^j \le 1$ for $i \in N$, $j \in M$ and $b_{ee} = \frac{1}{2}m$, we have $b_{ei} = m$. That is $X_e > X_i$, for $i \ne e$ by Lemma 23.1. Hence X_e is a strongly optimal alternative in X. □

Lemma 23.3 *Let X_k, $k \in N$ be alternatives in X. If $X_f \leqq X_e$, then (1) $b_{ek}^j \geq b_{fk}^j$, $j \in M$ for any $X_k \in X$; (2) $b_{ek} \geq b_{fk}$ for any $X_k \in X$; (3) $S_e \geq S_f$.*

Proof (1) Considering three cases of the values of b_{fk}^j. If $b_{fk}^j = 0$, the inequality holds. If $b_{fk}^j = 0.5$, then $A_f^j = A_k^j$. Since $X_f \leqq X_e$, from Definition 23.3, we have $A_f^j \preceq A_e^j$. It follows that $A_k^j \preceq A_e^j$. Hence, $b_{ek}^j \geq 0.5 = b_{fk}^j$. Finally, if $b_{fk}^j = 1$, then $A_k^j \prec A_f^j$. Together with $A_f^j \preceq A_e^j$, we have $A_k^j \prec A_e^j$ which implies $b_{ek}^j = 1$. Therefore (1) holds.

The assertions (2) and (3) are direct consequences of (1). □

Lemma 23.4 *If X_e is an optimal alternative in X, then $S_e = \max_{1 \leq i \leq n} S_i$.*

Proof It follows immediately from Definition 23.3 and Lemma 23.3. □

Lemma 23.5 *Let X_e and X_f be two alternatives in X. If $X_f \leq X_e$, then (1) $b_{ff} < b_{ef}$; (2) $S_f < S_e$.*

Proof (1) Since $X_f \leq X_e$, from Lemma 23.3 (1), we have $b_{ef}^j \geq b_{ff}^j = 0.5$, $j \in M$ and there exists at least one j_0 such that $A_f^{j_0} \prec A_e^{j_0}$. Hence $b_{ef}^{j_0} = 1 > b_{ff}^{j_0}$. Therefore, $b_{ef} = \sum_{j=1}^m b_{ef}^j > \sum_{j=1}^m b_{ff}^j = b_{ff}$. (2) By Lemma 23.3, we have $b_{ek} > b_{fk}$, for $k \in N$ and by (1), we have $b_{ff} < b_{ef}$. Consequently, $S_e = \sum_{k=1}^n b_{ek} > \sum_{k=1}^n b_{fk} = S_f$. This completes the proof of Lemma 23.3. □

Lemma 23.6 *Let X_e be an alternative in X. If $S_e = \max_{1 \leq i \leq n} S_i$, then X_e is a non-inferior alternative in X.*

Proof It follows immediately from Definition 23.3 and Lemma 23.3. □

Theorem 23.1 *Let X_e and X_f be two alternatives in X. If $S_f = \max_{1 \leq i \leq n,\, i \neq e} S_i$, then X_f is a non-inferior alternative in $X' = X \backslash \{X_e\}$.*

Proof Suppose that X_f is not a non-inferior alternative in X'. Then there exists some $X_k \in X'$ such that $X_f \leq X_k$. Hence, $S_f < S_k$ by Lemma 23.5, which is a contradiction to $S_f = \max_{1 \leq i \leq n,\, i \neq e} S_i$. This completes the proof of Theorem 23.1. □

Theorem 23.2 *Let X_e, X_k and X_f be alternatives in X, $S_e = \max_{1 \leq i \leq n} S_i$, where S_i is the superiority index of X_i. If $\left| S_k - S_f \right| > m - 1$, then the order of the elements between X_k and X_f is invariant in $X' = X \backslash \{X_e\}$.*

Proof Since $S_e = \max_{1 \leq i \leq n} S_i$, by Lemma 23.6, X_e is a non-inferior alternative in X. Now we prove that $b_{ie} \leq m - 1$ for each $i \in N$. If this is not the case, then there would be some i_0 such that $b_{i_0 e} = m$ or $b_{i_0 e} = m - \frac{1}{2}$. It implies that $b^j_{i_0 e} \geq \frac{1}{2}$ for each $j \in M$ and there exists some j_0 such that $b^{j_0}_{i_0 e} = 1$. It follows that $A^j_e \preceq A^j_{i_0}$ for each $j \in M$ and $A^{j_0}_e \prec A^{j_0}_{i_0}$ for some j_0. By Definition 23.3, we have $X_{i_0} \geq X_e$. By Lemma 23.5, $S_{i_0} > S_e$. This is a contradiction to the assumption $S_e = \max_{1 \leq i \leq n} S_i$. Note that $b_{ie} \geq 0$. Hence, we get $1 - m \leq b_{le} - b_{fe} \leq m - 1$. Consequently, for any X_l and X_f in X, we get $S'_l - S'_f = (S_l - b_{le}) - (S_f - b_{fe}) = (S_l - S_f) + (b_{fe} - b_{le})$, where S'_l and S'_f are the superiority indexes in $X' = X \backslash \{X_e\}$, respectively. Then, together with the assumption that $\left|S_k - S_f\right| > m - 1$, we have $S'_l > S'_f$ when $S_l > S_f$; $S'_f > S'_l$ when $S_f > S_l$. This completes the proof of Theorem 23.2. □

The above theorems show that the optimal alternative in X will rank in the first place followed by the second optimal one, which is optimal among the remaining ones. In general, there may not be any optimal alternative and so we will look for a non-inferior alternative. Theorem 23.1 suggests that if X_i has the largest superiority index among the alternative set X, then X_i is non-inferior in the set. This ranking of alternatives provides the decision maker a method to choose the most preferred one among the alternatives. From Theorem 23.2, we conclude the sufficient condition for the order between X_k and X_f to be invariant in X and $X' = X \backslash \{X_e\}$.

Remark 23.1 In the previous analysis, we only take advantage of partial order relation of two uncertain linguistic variables. However, there are other methods to rank fuzzy or interval numbers from which we can compare any two uncertain linguistic variables [4, 18]. To avoid complex comparisons, we choose the straightforward and simple method yet useful in real cases.

In the following, we develop a practical approach based on the superiority index to MCDM problems with uncertain linguistic information.

Procedure 1.
Step 1. Let $X = \{X_1, X_2, \cdots, X_n\}$ be a discrete set of alternatives. Let $C = \{C_1, C_2, \cdots, C_m\}$ be a predefined set of criteria or attributes. The decision maker give their preferences for each alternative with respect to each attribute, constructing the decision matrix $A = (A^j_i)_{n \times m}$, where A^j_i is an uncertain linguistic variable in a linguistic term set S.
Step 2. According to Definition 23.2, calculate b^j_{ik} and the superiority index of X_i over X_k, which is denoted by $b_{ik} = \sum_{j=1}^{m} b^j_{ik}$, $i, k \in N$.
Step 3. Calculate the overall superiority index of X_i: $S_i = \sum_{k=1}^{n} b_{ik}$, $i \in N$.
Step 4. Raking all the alternatives $X_i (i \in N)$ and select the best one(s) in accordance with the value of $S_i (i \in N)$. If there are two alternatives that have the same index, then extract the original information of such two alternatives in the decision matrix and compute their superiority indices separately, based on which the order can be determined.
Step 5. End.

23.4 Some Extensions

In this section, we generalize the proposed method into group decision making problem. In real evaluation and decision making problems, it is vital to involve several people and experts from different functional areas in decision making process. The challenge of group decision is taking into consideration the various opinions and preferences of the different individuals and deciding what action a group should take. In group decision analysis, the preference information of each expert is often aggregated to form a collective preference. The selection of the best alternative(s) is based on the derived collective decision information.

Let $X = \{X_1, X_2, \cdots, X_n\}$, $n \geq 2$ be a finite set of alternatives, $C = \{C_1, C_2, \cdots, C_m\}$, $m \geq 2$ be a finite set of attributes and $E = \{E_1, E_2, \cdots, E_q\}$, $p \geq 2$ be a finite set of experts, respectively. Suppose $v = (\nu_1, \nu_2, \cdots, \nu_q)^T$ be the weight vector of the decision maker, where $\nu_l \geq 0, l = 1, 2, \cdots, q$, $\sum_{l=1}^{n} \nu_l = 1$. Then, to select the best alternative(s), we recommend the following process.

Procedure 2.

Step 1. To a group MADM problem, suppose the lth decision maker constructs the decision matrix $A_l = (A_{il}^j)_{n\times m}$, where A_{il}^j is an uncertain linguistic variable in a linguistic term set S.

Step 2. Calculate the collective decision matrix $A = (A_i^j)_{n\times m}$ utilizing the average weighting operator, where $A_i^j = \sum_{l=1}^{q} v_l A_{il}^j$, $i \in N$, $j \in M$.

Step 3. According to the collective decision matrix A, calculate the superiority index of X_i over X_k, b_{ik}, and the overall superiority index of X_i: S_i, $i \in N$.

Step 4. Raking all the alternatives X_i, $i \in N$ and select the best one(s) in accordance with the value of S_i, $i \in N$.

Step 5. End.

As we can see, the difference of Procedure 2 from Procedure 1 is that in Procedure 2 it is calculated the superiority indices for the collective decision matrix. Alternatively, we may add the superiority index of alternative X_i of each decision maker $S_{ic} = \sum_{l=1}^{q} v_l S_i$ and rank the alternatives based on S_{ic}, $i \in N$. The choice of method depends on whether the group acts together as a unit or as separate individuals. After some adoption, the above procedure is also suitable to the group decision making problem with multi-granularity uncertain linguistic information.

The aforementioned methods do not use the weights information of the attributes. If we know the attribute weights, we can get a much more refined superiority index for each alternative. For example, the decision maker may give their preferences on the attribute weights by the analytical hierarchy process (AHP). Suppose $w = (w_1, w_2, \cdots, w_m)^T$ is the weight vector of attributes, then the superiority index of X_i over X_k is computed as $b_{ik} = \sum_{j=1}^{m} w_j b_{ik}^j$. These refined indexes avoid the indistinguishable situation of two alternatives in most cases.

Note that in a group decision making framework, a consensus reaching process is often needed to obtain the maximum degree of agreement among the experts on

Table 23.1 Uncertain linguistic matrix A

	C_1	C_2	C_3	C_4	C_5	C_6
X_1	$[s_1, s_2]$	$[s_2, s_3]$	$[s_{-1}, s_1]$	$[s_2, s_3]$	$[s_1, s_3]$	$[s_2, s_3]$
X_2	$[s_2, s_4]$	$[s_0, s_2]$	$[s_1, s_3]$	$[s_1, s_2]$	$[s_2, s_3]$	$[s_0, s_1]$
X_3	$[s_{-1}, s_1]$	$[s_3, s_4]$	$[s_0, s_3]$	$[s_2, s_4]$	$[s_0, s_2]$	$[s_3, s_4]$
X_4	$[s_{-1}, s_2]$	$[s_2, s_3]$	$[s_0, s_2]$	$[s_1, s_3]$	$[s_3, s_4]$	$[s_1, s_2]$

Table 23.2 Superiority indices of X_1 over X_k

	C_1	C_2	C_3	C_4	C_5	C_6	b_{1k}
X_1	0.5	0.5	0.5	0.5	0.5	0.5	3
X_2	0	1	0	1	0	1	3
X_3	1	0	0	0	1	0	2
X_4	1	0.5	0	1	0	1	3.5

the solution alternatives [1, 20]. Thus the proposed process can be considered as a selection process which should be used after the consensus process.

23.5 Numerical Examples

In this section, a problem of evaluating the technological innovation capability of enterprises is used to illustrate the developed approach. Consider the example discussed by [17].

A MCDM problem involves evaluating the technological innovation capability of enterprises. After preliminary screening, there are four enterprises denoted as X_1, X_2, X_3, X_4 remain for further evaluation. The attribute used are the following: (1) C_1: innovation input capacity; (2) C_2: innovation management capacity; (3) C_3: innovation inclined; (4) C_4: research and development capability; (5) C_5: manufacturing capacity; (6) C_6: marketing ability.

The four possible alternatives are to be assessed using the following linguistic term set: $S = \{s_{-4} =$ extremely poor, $s_{-3} =$ very poor, $s_{-2} =$ poor, $s_{-1} =$ slightly poor, $s_0 =$ fair, $s_1 =$ slightly good, $s_2 =$ good, $s_3 =$ very good, $s_4 =$ extremely good$\}$.

The decision maker gives the uncertain linguistic decision matrix as shown in Table 23.1.

To select the most suitable alternative(s), a brief description of the resolution process according to Sect. 23.3 is given below.

By the definitions in Sect. 23.3, we calculate b_{ik}^j and $b_{ik} = \sum_{j=1}^{6} b_{ik}^j$ (the superiority index of X_i over X_k). For alternative X_1, by computing the superiority index of X_1 over the other alternatives upon each attribute C_j, we get Table 23.2. Similarly, we obtain Tables 23.3, 23.4 and 23.5 for alternatives X_2, X_3, X_4 respectively.

Therefore, the superiority indexes of each alternative are: $S_1 = 3+3+2+3.5 = 11.5$, $S_2 = 3+3+3+2 = 11$, $S_3 = 4+3+3+4 = 14$, $S_4 = 2.5+4+2+3 = 11.5$.

Table 23.3 Superiority indices of X_1 over X_k

	C_1	C_2	C_3	C_4	C_5	C_6	b_{2k}
X_1	1	0	1	0	1	0	3
X_2	0.5	0.5	0.5	0.5	0.5	0.5	3
X_3	1	0	1	0	1	1	3
X_4	1	0	1	0	0	0	2

Table 23.4 Superiority indices of X_1 over X_k

	C_1	C_2	C_3	C_4	C_5	C_6	b_{3k}
X_1	0	1	1	1	0	1	4
X_2	0	1	0	1	0	1	3
X_3	0.5	0.5	0.5	0.5	0.5	0.5	3
X_4	0	1	1	1	0	1	4

Table 23.5 Superiority indices of X_1 over X_k

	C_1	C_2	C_3	C_4	C_5	C_6	b_{4k}
X_1	0	0.5	1	0	1	0	2.5
X_2	0	1	0	1	0	1	4
X_3	1	0	0	0	1	0	2
X_4	0.5	0.5	0.5	0.5	0.5	0.5	3

Rank all the alternatives X_i $(i = 1, 2, 3, 4)$ in accordance with S_i $(i = 1, 2, 3, 4)$. The ranking result of the alternatives is $X_3 \succ X_1 = X_4 \succ X_2$. Since X_1 and X_4 are not distinguishable at this moment, continue carry out the procedure for $\{X_1, X_4\}$ from the decision matrix. Then, we get $S_1' = 3+3.5 = 6.5$, $S_4' = 2.5+3 = 5.5$, which means $X_1 \succ X_4$. Finally, the ranking order of alternatives is $X_3 \succ X_1 \succ X_4 \succ X_2$. Thus the best alternative is X_3.

Note that the ranking order of alternatives by our method is somewhat different but very close to the method in [17]. However, both of the two methods choose alternative X_3 as the best alternative. Our method presents an alternative way to solve MCDM problem in a new manner and enriches the theory and methodology of decision analysis. Combing with other methods, the proposed method provides the decision maker a comprehensive and convincing result.

23.6 Concluding Remarks

In practical decision-making problems, the experts may use uncertain linguistic term according to a pre-established linguistic term set to express his/her preference on alternatives. In this paper, we have developed a new approach to solve the MCDM problem with uncertain linguistic information based on the superiority index. We have extended the method to the case of group decision making. We also have illustrated an example to see the computation process of the proposed method. The main features of our approach are: (1) it needs not to normalize the non-commensurate and conflicting criteria or attributes. (2) it makes the most of the order relation or partial order relation of the alternatives under each criteria. The proposed method provides the decision maker an alternative approach to make the decision.

The use of the proposed method is easy to be applied to support situations in which the preference information is in other forms, e.g., interval numerical number, triangular fuzzy number, intuitionistic fuzzy number or hybrid certain and uncertain information.

Acknowledgments This research was supported by National Natural Science Foundation of China (Grant No. 71301110) and the Humanities and Social Sciences Foundation of the Ministry of Education (Grant No. 13XJC630015) and also supported by Research Fund for the Doctoral Program of Higher Education of China (Grant No. 20130181120059).

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Chapter 24
Evaluation of the New Media's Influences in College Student Based on Analytic Hierarchy Process

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Abstract With the rapid development of new media, it is now a trend to carry out various works with it. The critical issue is how to analyse the characteristics of various types of new media at an in-depth level, and to find out the extent of their influences. This study attempts to find out new media's influences on college students, establish an evaluation system with Analytic Hierarchy Process (AHP), determine the weight of criteria, and measure the consistency of judgment matrix. With college students as the survey audience, data are collected and the influences of various types of new media are evaluated. According to the results, the five influential new media in descending order are Instant Messaging, Microblogging, Social Media, Blogs and Forums.

Keywords New media's influences · Analytic hierarchy process · Evaluation system

24.1 Introduction

With the continuous improvement of digital technology and escalating demand for applications, new media has undergone considerable development in recent years, and this rapid momentum is going to continue. Scholars focused on the study of the application and influence of new media recently. Hennig-Thurau et al. [3] introduced a new "pinball" framework of new media's impact on relationships with customers and identified key new media phenomena which companies should take into account when managing their relationships with customers. Zhou and Wang [15] introduced

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_24,

the application of new media for city marketing in Chinese cities. Christakou and Klimis [2] discussed the impact of blogs and social media on the reputation of banks and on their profitability. Brossard and Scheufele [1] pointed out that most people turn to search engines to find information and scientists payed more attention to the new media and "online" world. Meijer [8] concluded that new media support the trend of responsibilization: the police used new media to build virtual networks with citizens and engage them anywhere and anytime in the coproduction of safety.

Facing globalization and information technology, how to provide an effective, objective and scientific evaluation on new media's influences has become not only a commercial but also social topic of study [14]. The evaluation of new media's influences given by scholars generally consider all new media as a whole, compared with television, newspapers, radio and other traditional media; or it evaluates the influence of different websites on the Internet. Qiao [9] used AHP to evaluate the soft power of China media, which revealed that new media was developing rapidly, represented by SNS sites and microblogs, and its social influence had bypassed traditional print media and was almost comparable to the Internet. Yan [13] discussed the public's evaluation of networks and traditional media, through the data analysis of an urban and rural residents survey from China's 31 provinces, municipalities and autonomous regions in 2010. Kang and Zheng [5] gave a quantitative analysis with AHP on market influence indices of the domestic four portals (Sina, Sohu, Netease and Tencent) from an empirical perspective. It is rare to find evaluations on the features and influences of different types of new media in current studies. This paper attempts to propose a way to evaluate the influences of different types of new media, establish an evaluation system, and determine the criteria and the weight of coefficients. It also provides a quantitative analysis of their influences on college students from an empirical perspective. The study surveyed students in Sichuan University and collected data on the five most popular new media in China.

24.2 Establish an AHP-based Model on the Evaluation of New Media's Influences

1. Analytic Hierarchy Process (AHP)

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It has particular application in group decision making and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education [11].

2. Evaluation Criteria of New Media's Influences on College Students

Selection and design of evaluation criteria are the keys to establishing an evaluation system of new media's influences. Scholars have studied the evaluation system of traditional media and websites. Ingwersen [4] studied the feasibility and reliability of calculating impact factors for web sites. Tillotson [12] studied students' understanding of the need for Web site evaluation and their ability to articulate criteria for evaluation. Lin [6] developed an evolution model that integrates triangular fuzzy numbers and analytic hierarchy process to develop a fuzzy evaluation model which prioritized the relative weights of course website quality factors. Liu and Song [7, 10] proposed an evaluation system for network information quality. Based on existing research, this paper combines studies on new media in colleges and interviews of experts, and establishes an evaluation system from four dimensions: Information Quality, Propagation, Layout and Design and Website Operation. The details are as follows:

(1) Information Quality (B1): including Relevance (C1), Accuracy and Authority (C2), Novelty (C3), Breadth of Information (C4), Depth of Information (C5).
(2) Propagation (B2): including Accessibility (C6), Update rate of content (C7), Interactivity (C8), Hyperlinks (C9), Frequency of Usage(C10).
(3) Layout and Design (B3): including User Interface (C11), Information Organization (C12).
(4) Website Operation (B4): including Login Convenience (C13), Privacy (C14), Update Frequency of applications (C15), Free Resources (C16).

3. Hierarchy Structural Model of the Evaluation

A directed graph is drawn based on binary relations between the evaluation criteria and the sub-criteria. The reachability matrix is built up. Data is divided in regions and grades. The skeleton matrix is extracted. A Multilevel hierarchical directed graph is drawn. The hierarchical structure model is established as shown in Fig. 24.1.

24.3 Consistency Measurement of Judgment Matrix and Weight Coefficients

24.3.1 Establish the Judgment Matrix and Measure Consistency

We establish a judgment matrix by using the Delphi method. Anonymous questionnaires are distributed to experts, together with background materials of new media's influences. Their opinions are aggregated and fitted to the chart. Comparative analysis is conducted and feedback is given to the experts. The surveys to the experts are gradually finalized. The judgment matrix is then established and the relevant weights of coefficients are determined.

For Example, a judgment matrix of relevant importance among Ci is established under Propagation (B2) as shown in Table 24.1.

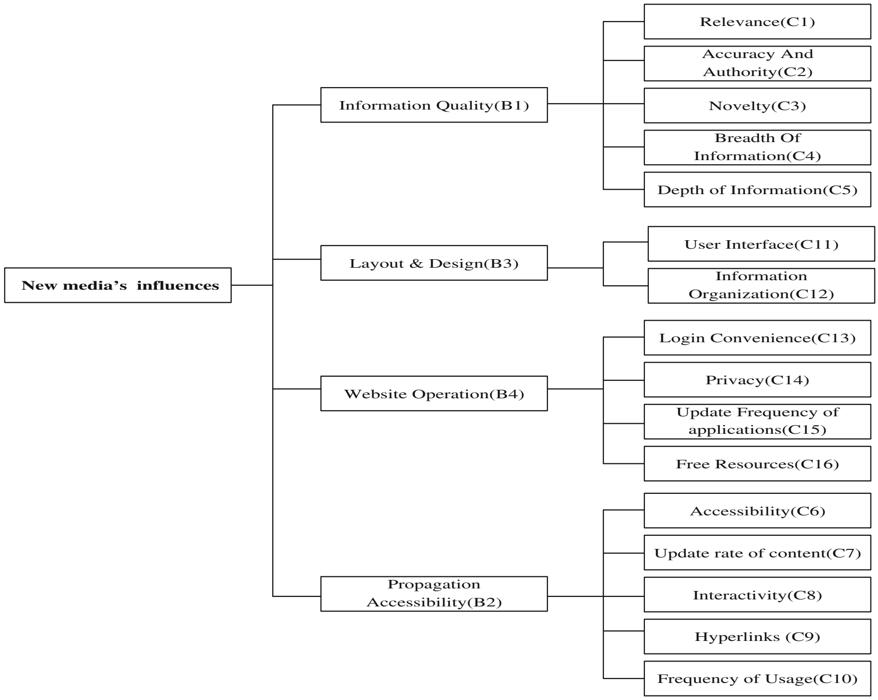

Fig. 24.1 The hierarchical structure model of new media influences

Table 24.1 A judgment matrix of relevant importance under Propagation (B2)

B2	C6	C7	C8	C9	C10	W_i
C6	1	11/8	12/7	12/7	8/9	0.22398
C7	8/9	1	11/7	11/7	4/5	0.19332
C8	7/9	7/8	1	1	2/3	0.16360
C9	7/9	7/8	1	1	2/3	0.16360
C10	11/9	11/4	13/7	1	8/9	0.25551

Next, the maximum eigenvalue $\lambda_{\max}$ and random consistency ratio CR of the matrix are obtained by root method.

1. Calculate the product of each row of the matrix by multiplying elements of the row, i.e.: $M_1 = 1 \times \frac{9}{8} \times \frac{9}{8} \times \frac{9}{7} \times \frac{8}{9} = 1.67$, $M_2 = 0.93$, $M_3 = 0.48$, $M_4 = 0.48$, $M_5 = 2.83$.
2. Calculate the n-th root of each Wi (n is the order of the matrix, where $n = 5$), i.e.: $\overline{W_1} = \sqrt[5]{M_1} = 1.14$, $\overline{W_2} = \sqrt[5]{M_2} = 0.98$, $\overline{W_3} = \sqrt[5]{M_3} = 0.83$, $\overline{W_4} = \sqrt[5]{M_4} = 0.83$, $\overline{W_5} = \sqrt[5]{M_5} = 1.30$.

Table 24.2 The average random consistency indexes after repeat calculation for 1,000 times

Order	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

Table 24.3 The weight coefficients of criteria in Hierarchy B

A: influences	B1: information quality	B2: propagation	B3: layout and design	B4: website operation
Weight coefficient	0.40	0.32	0.20	0.08

3. Normalise Wi, i.e. $W = \left[\overline{W_1}, \overline{W_2}, \overline{W_3}, \overline{W_4}, \overline{W_5}\right]^T = [1.14, 0.98, 0.83, 1.30]^T$, $\sum_i^4 \overline{W_i} = 1.14 + 0.98 + 0.83 + 1.30 = 5.08$, $W_1 = \frac{\overline{W_1}}{\sum_{j=1}^4 \overline{W_j}} = \frac{1.68179}{4.3064934} = 0.22398$.
   Similarly, we can get: $W_2 = 0.19332$, $W_3 = 0.16360$, $W_4 = 0.16360$, $W_5 = 0.25551$.
   Therefore, $W = [0.22398, 0.19332, 0.16360, 0.16360, 0.25551]^T$.
4. Calculate the maximum eigenvalue $\lambda_{\max}$ of the judgment matrix, i.e.:

$$AW = \begin{bmatrix} 1 & 9/8 & 9/7 & 9/7 & 8/9 \\ 8/9 & 1 & 8/7 & 8/7 & 4/5 \\ 7/9 & 7/8 & 1 & 1 & 2/3 \\ 7/9 & 7/8 & 1 & 1 & 2/3 \\ 10/9 & 5/4 & 10/7 & 10/7 & 1 \end{bmatrix} \times \begin{bmatrix} 0.2240 \\ 0.1933 \\ 0.1636 \\ 0.1636 \\ 0.2555 \end{bmatrix} = \begin{bmatrix} 1.2103 \\ 0.9708 \\ 0.8494 \\ 0.8494 \\ 1.2134 \end{bmatrix},$$

$$\lambda_{\max} = \sum_{j=1}^{n} \frac{(AW)_i}{n \times W_i} = \frac{(AW)_1}{n \times W_1} + \frac{(AW)_2}{n \times W_2} + \frac{(AW)_3}{n \times W_3} + \frac{(AW)_4}{n \times W_4} + \frac{(AW)_5}{n \times W_5}$$
$$= 5.1117.$$

5. Measure consistency of the judgment matrix. Consistent index $CI = \frac{\lambda_{\max} - n}{n-1} = \frac{5.1117-5}{5-1} = 0.0279$.

The average random consistency indexes of 1–10 order matrix after repeat calculation for 1,000 times are shown in the Table 24.2.

As the matrix is 5 order, the average $RI = 1.12$. Therefore the consistency ratio $CR = CI/RI = 0.0279/1.12 = 0.0249 < 0.10$. Hence, the judgment matrix and weight coefficient can be accepted.

24.3.2 Weight Coefficient of All Criteria

The weight coefficients of the criteria are determined by the establishment of judgment matrix and consistency measurement, as shown in Tables 24.3, 24.4, 24.5, 24.6 and 24.7.

Table 24.4 The weight coefficients of criteria under Hierarchy B1 (information quality)

B1: information quality	C1: relevancy	C2: accuracy authority	C3: novelty	C4: breath of information	C5: depth of information
Weight coefficient	0.1914	0.2629	0.1620	0.2218	0.1620

Table 24.5 The weight coefficients of criteria under Hierarchy B2 (propagation)

B2: propagation	C6: accessibility	C7: update rate	C8: interactivity	C9: hyperlinks	C10: frequency of usage
Weight coefficient	0.2240	0.1933	0.1636	0.1636	0.2555

Table 24.6 The weight coefficients of criteria under Hierarchy B3 (layout and design)

B3: layout and design	C11: user interface	C12: information organization
Weight coefficient	0.4615	0.5385

Table 24.7 The weight coefficients of criteria under Hierarchy B4 (website operation)

B4: website operation	C13: login convenience	C14: privacy	C15: update frequency	C16: free resources
Weight coefficient	0.2000	0.3600	0.1600	0.2800

24.4 The Application of AHP in the Evaluation of New Media's Influences

1. Composite Score of Different Types of New Media

In order to quantitatively determine new media's influences on college students, a questionnaire is designed based on evaluation criteria. Undergraduates in Sichuan University are selected to be objects of the survey, and questionnaires are randomly distributed. 340 questionnaires were given out, and 306 valid responses were collected. The response rate is 90.00 %. Data were analysed with SPSS13.0 (SPSS Inc, Chicago, IL) and the average score of each criteria is obtained. The scores of new media are listed in Fig. 24.2, after the combined calculation with the weight coefficients of each criteria.

In Fig. 24.2, it is shown that Instant Messaging scores the highest with 62.45, followed by Microblogging with 61.49. Forum scores the lowest at 32.48.

2. Score Comparison of Different New Media Under Hierarchy B

The scores of the five new media in information quality, propagation, layout and design and website design under Hierarchy B can be obtained according to the index weight coefficient and the index scores under Hierarchy C, as shown in Fig. 24.3.

Figure 24.3 shows the scores of five new media in information quality, propagation, layout and design and website design. These Hierarchy B index scores provide targeted guidance on the influence improvement of different types of new media.

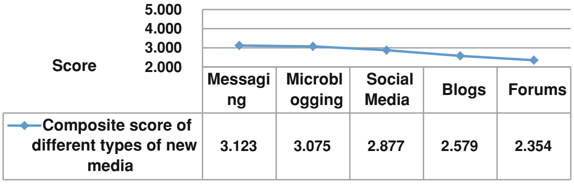

Fig. 24.2 Composite score of different types of new media

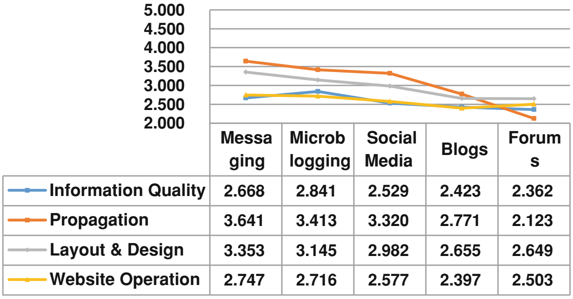

Fig. 24.3 Scores of five new media under Hierarchy B

For example, Instant Messaging scores the highest in propagation, layout and design and website design, but its score in information quality ranks the second. Thus, Instant Messaging may consider strengthening its information control to improve the authenticity, objectivity and security of information.

24.5 Analysis and Recommendation

1. Based on the survey results, the various new media's influences on college students rank as follows in descending order: Instant Messaging, Microblogging, Social Media, Blog, and Forum. This result is in line with student user habits, as Instant Messaging and microblogging fit the needs of users seeking to utilize fragmented time. These platforms provide convenient access and timely information dissemination.
2. Schools may use an integrated system to apply new media in students' affairs. According to their characteristics, different types of new media should be focused and utilized. Currently, Instant Messaging and Microblogging have great influences among students, Schools need to take initiatives to create interactive accounts on these platforms and pay close attention to student's thought trends to strengthen guidance and management. The blogs score the highest among new media in terms of information depth. Therefore, schools may build an academic and cultural platform with an in-depth ideology through blogs.
3. The survey unveils scores of new media under each criteria. Developers and operators of new media may further work on need analysis and data mining according to the results. They may also focus on enhancing the performance and

user experience of the specific type of new media, to increase user satisfaction and improve their market competitiveness and influence.

Acknowledgments This research was supported by the Fundamental Research Funds for the Central Universities of Sichuan University (Grant No. SKSZ201416) and Sichuan Province Training Programs of Innovation and Entrepreneurship for Undergraduates (Grant No. 201310610190). The author gratefully acknowledges Chan Han, Lu Cao et al who supported the research.

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Chapter 25
A New Approach to Job Evaluation Through Fuzzy SIR

Hossein Safari, Mohammad Aghighi, Fatemeh Mirzaei Rabor and Virgílio António Cruz-Machado

Abstract Job evaluation is carried out in order to choosing competent employees and compensates their services. To help in this selection, Occupational Information Network factors are used to assessing the various requirements that are necessary for doing the job. Job evaluation is a multiple criteria decision making in which multifarious criteria are required to be evaluated simultaneously. In this paper, a multi-criteria group decision making model has been developed based on fuzzy set theory to efficiently deal with the ambiguity of the decision making problems in practical cases to evaluate the jobs and comparing them. Namely it was used an integrated Delphi and fuzzy SIR for job evaluation. Firstly we used Delphi method to extract the weight of criteria in job evaluation. The importance of various criteria was gathered by Delphi method as linguistic variables. The proposed model utilizes superiority and inferiority ranking (SIR) method in fuzzy environment for comparing the performance of alternatives. Job evaluation and its problems as well as subjective judgment of appraiser are vague and uncertain, and so fuzzy set theory helps to convert decision maker preferences and judgments into meaningful results by applying linguistic values to measure each criterion with respect to every jobs.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_25,

Keywords Human resources · Job evaluation · Multi criteria decision making · Fuzzy logic · SIR

25.1 Introduction

Job evaluation usually includes an extensive analysis of the roles, the objectives and the corresponding actions and achievements of the jobs [12]. The outcome of this analysis is the establishment of structures that aid the comparison among the jobs and support the evaluator(s) to make consistent and reasonable judgments.

Job evaluation helps in developing and maintaining a pay structure by comparing the relative similarities and differences in the content and the value of jobs [23]. The purpose of job evaluation is to eliminate the pay inequalities. Job evaluation places the value of a job. This value may be expressed indirectly through ranking, classification, factor comparison or a point scheme. When the values of a job description are determined, they may be translated in terms of money according to some bases, to have a balanced wage structure in the organization. Job evaluation systems are developed and validated on the basis of a select sample of jobs known as benchmark or key jobs. The next step is to establish the compensable factors that determine the relative worth of a job [21]. The number of compensable factors should vary from one job to another. Several attempts have been made to reduce job evaluation problems to a multi-criteria decision-making problem and then solved by several available methods.

Gupta and Ahmed [17] extended the analytical work and developed a linear goal programming model for determining the relative worth of various levels of job factors comprising the significant portion of a job. Developing a suitable approach for job evaluation is however a challenging research task. There are many studies about job evaluation and evaluation approach in traditional form of personnel management but there are a few studies about job evaluation in fuzzy environment. The aim of this study is job evaluation in fuzzy environment. The first step in this study is extracting criteria for job evaluation. So it is very important to choose a scientific and rational evaluation criterion which is the first step to conduct evaluation. Then a question rises up here and that is how this importance weight could be calculated? In the next step another question is rises up and it's that which MCDM method is suitable for job evaluation. For this we proposed a new multi criteria decision making model for job evaluation. Our proposed decision making model is made of two methods: Delphi, and fuzzy SIR.

The fuzzy set theory approaches could resemble human reasoning in use of approximate information and uncertainty to generate decisions. Furthermore, fuzzy logic has been integrated with MCDM to deal with vagueness and imprecision of human judgment. The O*Net criteria in 6 category is selected for job evaluation and Delphi method is used for the determination of the relative importance of evaluation criteria. The proposed model utilizes superiority and inferiority ranking (SIR) method and it provides six preference structures in order to compare the performance of alternatives' criteria.

This paper outlines the theoretical basis of job evaluation and then Occupational information network (O*Net) and its approach to the job evaluation has been addressed. Fuzzy logic that is the basis for this research analysis has been thoroughly explored and then the research methodology is discussed. Superiority and Inferiority ranking (SIR) techniques and subsequently expression of this techniques in the fuzzy space are shaping the next phase of this article. Using fuzzy SIR techniques in Job analysis—that is one of the innovations of this study—and its implementation in a typical sample and then expression of conclusions from findings form the final stages of this research.

25.2 Literature Review

25.2.1 Job Evaluation

Job evaluation is a technique which swelled during the Fordist period [15] because they harmonized with the Fordist manufacture structure, which might include large-scale mass production, special-purpose machinery and the moving assembly line, the combination of standardized parts, and the fragmentation of lab our skills under the hierarchical and bureaucratic form of works characterized by a centralized management [3].

It is often used to provide a rational framework for planning and establishing a fair payroll structure by comparing the relative similarities and differences in the content of jobs and placing the value of them [16]. The main principle of job evaluation is 'equal pay for equal work'. This principle refers to workers in the same-value job, performing the same performance equally well, being paid equally and to those in the different-value job being paid differently [13].

Job evaluations are systematic procedures used to determine the relative worth of jobs [29]. The goal of using job evaluation is to determine a hierarchy of positions that is based on the relative contribution of each job to a firm [28].

When the values of jobs are determined, they can be translated in terms of money according to some base, to have a balanced wage structure in the organization [16].

Job evaluation aims to:

- Establish the relative value or size of jobs (internal relativities) based on fair, sound and consistent judgments;
- Produce the information required to design and maintain equitable and defensible grade and pay structures;
- Provide as objective as possible a basis for grading jobs within a grade structure, thus enabling consistent decisions to be made about job grading;
- Enable sound market comparisons with jobs or roles of equivalent complexity and size;

- Be transparent—the basis upon which grades are defined and jobs graded should be clear;
- Ensure that the organization meets equal pay for work of equal value obligations [4].

For the job evaluation a considerable number of approaches have been developed and used. The most simple of them treat the problem providing a ranking or a classification of the jobs based on a simple comparative process or on a simple points factor rating system [4]. One common approach consist in providing a ranking of the jobs according to the perception of their relative size. This approach is characterized by low degree of rationality since the judgement of the relative sizes of the jobs is not based on a kind of standards or measures. Another approach utilizes a scale for the classification of the jobs. Different levels of grades are assigned into a number of characteristics such as "decision making", "knowledge required" and "equipment used". Every job is posed on a position on the total scale by its evaluation on the characteristics.

Another commonly used approach is based on the comparison of the jobs with an internal benchmark one. This approach cannot be applied in cases where there is a small number of jobs and a high degree of differentiation among the jobs does not exist. Otherwise it is difficult to define a job which can be used as a benchmark.

The most common approach is the "point factor rating" [9]. According to this method the evaluation of the jobs derives from a multiattribute value system. The principles of this value system are based on the essential of the Multiattribute Utility Theory [20]. This approach is widely used by management consultants and usually provides reasonable results but lacks on the estimation of the weights of the attributes and on the evaluation of the jobs on the criteria. Actually, the factors weights are estimated through a survey analysis or are directly expressed by an expert or a management consultant.

The criteria involved in Multi-Criteria Decision Making (MCDM) are often conflicting, non-commensurable and fuzzy in nature. The concept of decision-making in fuzzy environment has been introduced by Bellman and Zadeh. In this paper, an attempt has been made to rank the jobs in fuzzy environment for the jobs having different factors and each factor having different levels.

Some of the researches have been done in the field of job evaluation in line with the title of this article are as described in Table 25.1.

25.2.2 The O∗NET Content Model

The Content Model is the conceptual basis of O*NET. The Content Model provides a framework that identifies the most important types of information about work and integrates them into a theoretically and empirically sound system [25].

The Content Model was developed using research on job and organizational analysis. It embodies a view that reflects the character of occupations (via job-oriented

Table 25.1 Previous research

Author(s)	Research title	Analysis method	Results
Charnes and Ferguson [11]	Optimal estimation of executive compensation by linear programming	Linear programming	Developing linear programming model for the determination of executive salary
Llewellen [22]	Linear programming	Linear programming	Developing relative weights to be assigned to points, given various factors in the point system of evaluation
Zimmermann [34]	Fuzzy programming and linear programming with several objective functions	Fuzzy linear programming	Developing fuzzy mathematical programming to solve the problems with several objective functions
Yager [31]	Mathematical programming with fuzzy constraints and preference on the objectives	Fuzzy mathematical programming	Developing mathematical programming with fuzzy constraints and preference on the objectives
Narasimhan [24]	Goal programming in fuzzy environment	Goal programming in fuzzy environment	Developing goal programming in fuzzy environment
Rubin and Narasimhan [27]	Fuzzy goal programming with nested priorities	Fuzzy goal programming	Developing fuzzy goals and their priorities
Ahmed and Walters [2]	A model for optimal determination of job evaluation factors	Linear programming	Evaluation of relative worth of various levels of job factors
Feng [14]	A method using fuzzy mathematical programming to solve the vector maximum problem	Fuzzy mathematical programming	Modifying the concept of real world decision-making problem

(Continued)

Table 25.1 (Continued)

Author(s)	Research title	Analysis method	Results
Ying-Yung [32]	A method using fuzzy mathematics to solve vector maximum problem	Fuzzy mathematical programming	Developing fuzzy mathematical programming for solving the job evaluation problems
Ahmed [1]	An analytical technique to evaluate factor weights in job evaluation	Linear programming	Developing a method for job evaluation

Fig. 25.1 O∗Net model

descriptors) and people (via worker-oriented descriptors). The Content Model also allows occupational information to be applied across jobs, sectors, or industries (cross-occupational descriptors) and within occupations (occupational-specific descriptors). These descriptors are organized into six major domains, which enable the user to focus on areas of information that specify the key attributes and characteristics of workers and occupations (Fig. 25.1).

- Worker Characteristics—enduring characteristics that may influence both performance and the capacity to acquire knowledge and skills required for effective work performance. Worker characteristics comprise enduring qualities of individuals that may influence how they approach tasks and how they acquire work-relevant knowledge and skills.
- Worker Requirements—descriptors referring to work-related attributes acquired and/or developed through experience and education. Worker requirements represent developed or acquired attributes of an individual that may be related to work.
- Experience Requirements—requirements related to previous work activities and explicitly linked to certain types of work activities. This domain includes information about the typical experiential backgrounds of workers in an occupation or group of occupations including certification, licensure, and training data.

- Occupation-Specific Information—variables or other Content Model elements of selected or specific occupations. Occupation-specific information details a comprehensive set of elements that apply to a single occupation or a narrowly defined job family.
- Workforce Characteristics—variables that define and describe the general characteristics of occupations that may influence occupational requirements. Organizations do not exist in isolation. They must operate within a broader social and economic structure. To be useful, an occupational classification system must incorporate global contextual characteristics. O∗NET provides this information by linking descriptive occupational information to statistical labor market information.
- Occupational Requirements—a comprehensive set of variables or detailed elements that describe what various occupations require. This domain includes information about typical activities required across occupations.

In this paper, an attempt has been made to rank the jobs based on O∗Net factors.

25.3 Fuzzy Logic

Fuzzy set theory first was introduced by Zadeh [33] to map linguistic variables to numerical variables within decision making processes. Then the definition of fuzzy sets were manipulated to develop Fuzzy Multi-Criteria Decision Making (FMCDM) methodology by Bellman and Zadeh [5] to resolve the lack of precision in assigning importance weights of criteria and the ratings of alternatives against evaluation criteria.

A fuzzy set is characterized by a membership function, which assigns to each element a grade of membership within the interval (0, 1), indicating to what degree that element is a member of the set [6]. As a result, in fuzzy logic general linguistic terms such as “bad”, “good” or “fair” could be used to capture specifically defined numerical intervals. A tilde “∼” will be placed above a symbol if the symbol represents a fuzzy set. A triangular fuzzy number (TFN) $\widetilde{M}$ is shown in Fig. 25.1. A TFN is denoted simply as (l, m, u). The parameters l, m and u denote the smallest possible value, the most promising value and the largest possible value that describe a fuzzy event [19]. When $l = m = u$, it is a non-fuzzy number by convention [10]. Each TFN has linear representations on its left and right side such that its membership function can be defined as [19] (Fig. 25.2).

Each TFN has linear representations on its left and right side such that its membership function can be defined as [19]

$$\mu_{\widetilde{M}} \begin{cases} 0, x < l \\ (m - l), l \le x \le m \\ (u - m), m \le x \le u \\ 0, x > u. \end{cases} \tag{25.1}$$

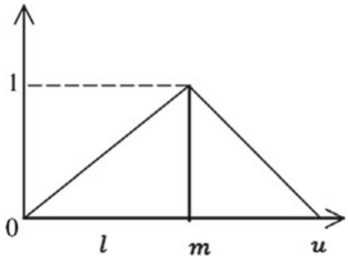

Fig. 25.2 A triangular fuzzy number, $\widetilde{M}$ [19]

- $\times$: multiply fuzzy numbers, e.g. assuming two triangular fuzzy numbers $\widetilde{A} = (a_1, b_1, c_1)$, $\widetilde{B} = (a_2, b_2, c_2)$, $\widetilde{A} \times \widetilde{B} = (a_1 \times a_2, b_1 \times b_2, c_1 \times c_2)$.
- /: divide fuzzy numbers, e.g.: assuming two triangular fuzzy numbers $\widetilde{A} = (a_1, b_1, c_1)$, $\widetilde{B} = (a_2, b_2, c_2)$, $\widetilde{A} \div \widetilde{B} = (a_1 \div a_2, b_1 \div b_2, c_1 \div c_2)$.

25.4 Methodology

Based on literature review we found 6 criteria and 20 sub-criteria. In this study we use an integrated Delphi, fuzzy SIR for job evaluation. Firstly we used Delphi method to extract the weight of criteria in job evaluation. The importance weights of various criteria and the ratings of qualitative criteria are considered as linguistic variables. In order to evaluate the weights of criteria that were obtained by Delphi method, geometric mean was used. We then evaluated the job evaluation by SIR.

25.5 SIR Method

This method is one of the new and relative complex Multi Criteria Decision Making methods. There are preference functions in this method such as PROMETHEE, which after calculating the preference of each alternative to the criteria, and finding the paired preference functions of alternatives due to the criteria, superiority and inferiority matrix must be formed. At the next step weighted flow matrix is formed such as SAW and TOPSIS techniques, and alternatives can be ranked by calculating the flows.

In SIR method we use such scores that these scores are obtained by comparing values of criteria. Assume that we have two alternatives A and $\widetilde{A}$. To calculate the scores for these ordinal data with respect to criterion g (to be maximized), we use the preference structure $\{P, I\}$ as follows: APA' (A is preferred to A') iff $g(A) > g(A')$; AIA' (A is indifferent to A') iff $g(A) = g(A')$, Where $g(A)$ and $g(A')$ are the criteria values for A and A' on criterion g.

Table 25.2 Generalized criteria

Criterion	Criterion	Criterion
Type 1: True criterion with linear preference	Type 2: Quasi criterion	Type 3: Criterion with linear preference
$f(d)=\begin{cases}1, \text{ if } & d\geq 0\\ 0, \text{ if } & d<0\end{cases}$	$f(d)=\begin{cases}1, \text{ if } & d\geq q\\ 0, \text{ if } & d<q\end{cases}$	$f(d)=\begin{cases}1, & \text{if } & d\geq p\\ \frac{d}{p}, & \text{if } & 0<d\leq p\\ 0, & \text{if } & d\leq 0\end{cases}$
Type 4: Level criterion	Type 5: Criterion with linear preference and indifference area	Type 6: Gaussian criterion
$f(d)=\begin{cases}1, & \text{if } & d\geq p\\ \frac{1}{2}, & \text{if } & q<d\leq p\\ 0, & \text{if } & d\leq q\end{cases}$	$f(d)=\begin{cases}1, & \text{if } & d\geq p\\ \frac{d-q}{p-q}, & \text{if } & q<d\leq p\\ 0, & \text{if } & d\leq q\end{cases}$	$f(d)=\begin{cases}1-e^{\frac{-d^2}{\sigma^2}}, & \text{if } & d\geq 0\\ 0, & \text{if } & d<0\end{cases}$

First we must form a decision matrix. In any multi-criteria decision making method, the decision maker determines a number of criteria. Let $A_1, A_2, \cdots, A_m$ be m alternative and $(g_1, g_2, \cdots, g_n)$ be n cardinal criteria. $g_j(A_i)$ is the performance of the ith alternative A_i with respect to the jth criteriong $j \cdot g_j(\cdot)$ is a real-valued function $(i = 1, 2, \cdots, m;\ j = 1, 2, \cdots, n)$.

$$D\begin{bmatrix} g_1(A_1) & g_2(A_1) & g_3(A_1) & g_n(A_1)\\ g_1(A_2) & g_2(A_2) & \cdots & g_n(A_2)\\ \vdots & . & \ddots & \vdots\\ g_1(A_m) & g_2(A_m) & \cdots & g_n(A_m)\end{bmatrix}.$$

Then we weight each criterion. In this step we can use some method like AHP or Shannon entropy. Now we can compare the criteria value on each criterion [30]. The generalized criterion is calculated using the elements of the decision matrix. The differences between criteria values are used to estimate the intensity of the preference of A over A' as per Eq. (25.1), $P(A, A') = f(d) = f(g(A) - g(A'))$, $P(A, A')$ is the preference of A over A'.

Brans et al. [7] proposed six generalized criterion types which can be used to capture the characteristics of functions that represent the specified criteria. According to the attitude towards the preference structure and intensity of preference, the decision maker selects the generalized criteria (along with its associated parameter). Table 25.2 lists the types of generalized criteria. It should be noted that the intensity of preference for Types 3, 5, and 6 changes gradually from 0 to 1.

In this research, Criterion with linear preference and indifference area has been used. For each alternative A_i, the superiority index $S_j(A_i)$ and inferiority index $I_j(A_i)$ with respect to the jth criterion are calculated as follows: $S_j(A)_i = \sum_{k=1}^{m} P(A_i, A_k) = \sum_{k=1}^{m} f_j(g_j(A_i) - g_j(A_k)), I_j(A)_i = \sum_{k=1}^{m} P(A_k, A_i) = \sum_{k=1}^{m} f_j(g_j(A_k) - g_j(A_i))$.

The superiority and inferiority indexes are used to form superiority matrix (S-matrix) and inferiority matrix (I-matrix). S-matrix provides information about the intensity of superiority of each alternative on each criterion, whereas, I-matrix provides information about the intensity of inferiority:

The superiority matrix (S-matrix):

$$S\begin{bmatrix} S_1(A_1) & S_2(A_1) & S_3(A_1) & S_n(A_1) \\ S_1(A_2) & S_2(A_2) & \cdots & S_n(A_2) \\ \vdots & . & \ddots & \vdots \\ S_1(A_m) & S_2(A_m) & \cdots & S_n(A_m) \end{bmatrix}.$$

The inferiority matrix (I-matrix):

$$I\begin{bmatrix} I_1(A_1) & I_2(A_1) & I_3(A_1) & I_n(A_1) \\ I_1(A_2) & I_2(A_2) & \cdots & I_n(A_2) \\ \vdots & . & \ddots & \vdots \\ I_1(A_m) & I_2(A_m) & \cdots & I_n(A_m) \end{bmatrix}.$$

The superiority and inferiority indexes (arranged in S- and I-matrix, respectively) are aggregated into two types of global preference indexes: superiority flow (S-flow) $\varphi^{\succ}(\cdot)$ and inferiority flow (I-flow) $\varphi^{\prec}(\cdot)$. The S- and I-flows are basically the intensity of each alternative. The former flow measures how an alternative is globally superior to (or outranks) all the others, whereas, the latter flow measures how an alternative is globally inferior to (or outranked by) all the others.

There are two aggregation procedures which are used to obtain S- and I-flows. These are SAW and TOPSIS procedures. The SAW is considered the simplest and clearest procedure. It is usually used as a benchmark to compare the results obtained from other procedures. The TOPSIS is considered very logical way of approaching the discrete MCDM problems. However, it is computationally more complex than SAW [18]. The following sub-sections describe the structures of SAW and TOPSIS procedures.

SAW procedure; S^{-} and I-flows are calculated based on the weight of criteria (w_j) as follows:

$$\varphi^{\succ}(A_i) = \sum_{j=1}^{n} W_j S_j(A_i), \quad \varphi^{\prec}(A_i) = \sum_{j=1}^{n} W_j I_j(A_i), \tag{25.2}$$

where $\sum_{i=1}^{n} W_j = 1\ (W_j \geq 0)$.

TOPSIS procedure; S-flow is calculated based on ideal solution A_S^{+} and negative-ideal solution A_S^{-} for the superiority matrix (S-matrix) as follows:

$$\varphi^{\succ}(A_i) = \frac{S_i^-(A_i)}{S_i^-(A_i) - S_i^+(A_i)}, \tag{25.3}$$

$$S_i^+(A_i) = \left\{ \sum_{j=1}^{n} \left| W_j(S_j(A_i) - S_j^+) \right|^{\lambda} \right\}^{1/\lambda} \quad (0 \le \lambda \le \infty), \tag{25.4}$$

$$S_i^-(A_i) = \left\{ \sum_{j=1}^{n} \left| W_j\left(S_j(A_i) - S_j^-\right) \right|^{\lambda} \right\}^{\frac{1}{\lambda}} \quad (0 \le \lambda \le \infty), \tag{25.5}$$

$$A_S^+ = (\max_i S_1(A_i), \cdots, \max_i S_n(A_i)) = (S_1^+, \cdots, S_n^+), \tag{25.6}$$

$$A_S^- = (\max_i S_1(A_i), \cdots, \max_i S_n(A_i)) = (S_1^-, \cdots, S_n^-). \tag{25.7}$$

I-flow is calculated based on ideal solution I_S^+ and negative-ideal solution I_S^- for the inferiority matrix (I-matrix) as follows:

$$\varphi^{\prec}(A_i) = \frac{I_i^+(A_i)}{I_i^-(A_i) - I_i^+(A_i)}, \tag{25.8}$$

$$I_i^+(A_i) = \left\{ \sum_{j=1}^{n} \left| W_j(I_j(A_i) - I_j^+) \right|^{\lambda} \right\}^{1/\lambda} \quad (0 \le \lambda \le \infty), \tag{25.9}$$

$$I_i^-(A_i) = \left\{ \sum_{j=1}^{n} \left| W_j(I_j(A_i) - I_j^-) \right|^{\lambda} \right\}^{1/\lambda} \quad (0 \le \lambda \le \infty), \tag{25.10}$$

$$A_I^+ = (\max_i I_1(A_i), \cdots, \max_i I_n(A_i)) = (I_1^+, \cdots, I_n^+), \tag{25.11}$$

$$A_I^- = (\max_i I_1(A_i), \cdots, \max_i I_n(A_i)) = (I_1^-, \cdots, I_n^-). \tag{25.12}$$

Net and relative flows; Net flow (n-flow) and relative flows (r-flow) are calculated utilizing S- and I-flows as per Eqs. (25.2) and (25.3):

$$\varphi_n(A_i) = \varphi^{\succ}(A_i) - \varphi^{\prec}(A_i), \tag{25.13}$$

$$\varphi_r(A_i) = \frac{\varphi \succ (A_i)}{(\varphi \succ (A_i) - \varphi \prec (A_i))}. \tag{25.14}$$

Four complete ranking are obtained from $S-$, $I-$, $n-$ and r-flows. These are S-ranking ($\Re_>$), I-ranking ($\Re_<$), n-ranking ($\Re_n$), and r-ranking ($\Re_r$). The S-ranking $\Re_> = P_>, I_>$, is obtained based on the descending order of $\varphi \prec (A_i)$ as follows:

$$A_i P > A_k \text{ iff } \varphi^{\succ}(A_i) > \varphi^{\succ}(A_k), \tag{25.15}$$

$$A_i I > A_k \text{ iff } \varphi^{\succ}(A_i) > \varphi^{\prec}(A_k). \tag{25.16}$$

The I-ranking $\Re_< = P_<, I_<$, obtained based on the ascending order of $\varphi^{\prec}(A_i)$ as follows:

$$A_i P < A_k \text{ iff } \varphi^{\prec}(A_i) > \varphi^{\prec}(A_k), \tag{25.17}$$

$$A_i I < A_k \text{ iff } \varphi^{\prec}(A_i) = \varphi^{\prec}(A_k). \tag{25.18}$$

The n-ranking and r-ranking are obtained based on the descending order of n- and r-flows, respectively. Partial ranking ($\Re$) is obtained by combining S-ranking $\Re_>$, and I-ranking $\Re_<$, in a partial ranking structure as follows: $\Re = (P, I, R) = \Re_> \bigcap \Re_<$. The intersection principle, proposed by Brans et al. [7] and Roy et al. [26], is adopted to compare any two alternatives as follows:

Preference relation P: APA' iff $(AP > A'$ and $AP < A')$ or $(AP < A'$ and $AI > A')$ or $(Ai > A'$ and $Ap < A')$.

Indifference relation I: $AIA^{'}$ iff $(AI > A^{'}$ and $AI < A^{'})$.

Incomparability relation R: ARA' iff $(AP > A'$ and $A'P < A)$ or $(A'P < A$ and $AP > A')$ (Table 25.3).

25.6 An Application

Discussed techniques for job evaluation has been implemented in office of education of KASHAN University and in a nine-member sample. Seems to be due to the nature of multi-criteria decisions on job evaluation and linguistic variables obtained from the questionnaire, using the multi-criteria decision making models in fuzzy environment is very efficient. According to the positive and negative flows of each criterion in the first place, and every job in total, final decision can be made on the basis of net-flow and or relative-flow of every job. For this reason, from various multi-criteria decision making techniques, SIR method is selected. Steps for performing this technique in the selected sample are as follows:

Step 1. The weights of evaluation criteria

We adopt Delphi method to evaluate the weights of different criteria of O∗Net for job evaluation in selected sample jobs.

Step 2. Transfer the linguistic scales to the corresponding fuzzy numbers

According to SIR method we first construct the decision matrix. The numbers in this matrix are the value of each alternative (jobs). We use geometric mean method suggested by Buckley [8] for computing the mean of responses (Table 25.4).

Step 3. Construct the Fuzzy comparison matrix for the relative importance of each jobs according to a special criteria.

For example comparison matrix for the jobs based on Worker Characteristics is as follow:

Table 25.3 Fuzzy values for decision matrix

Geo-Worker metric mean	Worker characteristics			Worker requirement			Experience requirement			Occupation-specific information			Workforce characteristic			Occupational requirement		
a	5.47	6.60	7.54	5.92	7.21	8.49	3.76	5.32	6.62	4.00	5.00	6.00	1.50	2.69	3.83	0.28	2.65	4.61
b	5.44	6.85	8.24	0.40	3.80	6.00	3.13	4.27	5.48	0.32	3.09	5.18	0.02	1.86	3.94	2.65	4.00	5.20
c	3.71	4.30	5.79	3.44	4.78	6.00	0.37	3.55	5.62	0.30	3.00	4.90	4.79	5.86	7.33	0.01	1.15	2.78
d	0.28	3.08	4.95	5.66	6.89	7.75	2.45	3.33	4.61	5.98	7.36	8.32	0.02	1.48	3.31	0.30	2.89	4.82
e	5.86	6.79	7.98	3.20	4.37	5.73	0.33	3.42	5.66	5.09	6.04	7.21	0.39	3.71	5.73	0.02	1.41	3.22
f	0.41	3.96	6.16	6.88	8.28	9.21	3.64	5.10	6.45	3.46	4.18	5.48	2.24	3.61	4.90	0.10	1.41	2.71
g	0.48	4.55	6.69	0.02	1.58	3.46	4.28	5.14	6.34	4.45	5.91	7.02	0.28	2.75	4.68	0.01	1.26	2.91
h	7.74	9.10	9.74	0.38	3.76	5.98	5.57	6.73	7.95	4.28	5.14	6.34	3.96	5.37	6.64	0.10	1.41	2.71
i	7.48	8.72	9.49	0.36	3.61	5.83	4.47	5.70	6.93	2.74	4.18	5.33	0.30	2.89	4.82	0.26	2.51	4.47

a registry expert; *b* expert of student transfers; *c* expert of filing and archive; *d* expert of alumni; *e* expert of graduate affairs; *f* expert of preparing thesis; *g* expert of talented students; *h* Monitoring and Evaluation Expert Office of Education; *i* expert of executive board of faculty member attraction

Table 25.4 Fuzzy comparison matrix for the relative importance of each jobs according to worker characteristic

Worker[a]	Job 1			Job 2			Job 3			Job 4			Job 5		
Job 1	0.00	0.00	0.35	0.00	0.00	0.35	0.00	0.29	0.64	0.26	0.60	1.00	0.00	0.00	0.28
Job 2	0.00	0.06	0.46	0.00	0.00	0.47	0.00	0.28	0.76	0.24	0.59	1.00	0.00	0.00	0.40
Job 3	0.00	0.00	0.05	0.00	0.00	0.06	0.00	0.00	0.35	0.00	0.16	0.92	0.00	0.00	0.00
Job 4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.78	0.00	0.00	0.00
Job 5	0.00	0.05	0.42	0.00	0.00	0.42	0.03	0.39	0.71	0.45	0.69	1.00	0.00	0.00	0.35
Job 6	0.00	0.00	0.11	0.00	0.00	0.12	0.00	0.00	0.41	0.00	0.00	0.98	0.00	0.00	0.05
Job 7	0.00	0.00	0.20	0.00	0.00	0.21	0.00	0.00	0.50	0.00	0.00	1.00	0.00	0.00	0.14
Job 8	0.10	0.62	0.71	0.00	0.22	0.72	0.97	0.86	1.00	1.00	1.00	1.00	0.00	0.24	0.65
Job 9	0.00	0.53	0.67	0.00	0.16	0.67	0.85	0.79	0.96	1.00	1.00	1.00	0.00	0.17	0.61

Worker[a]	Job 6			Job 7			Job 8			Job 9		
Job 1	0.00	0.38	1.00	0.00	0.23	1.00	0.00	0.00	0.00	0.00	0.00	0.01
Job 2	0.00	0.37	1.00	0.00	0.22	1.00	0.00	0.00	0.08	0.00	0.00	0.13
Job 3	0.00	0.00	0.90	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00
Job 4	0.00	0.00	0.76	0.00	0.00	0.75	0.00	0.00	0.00	0.00	0.00	0.00
Job 5	0.00	0.47	1.00	0.00	0.33	1.00	0.00	0.00	0.04	0.00	0.00	0.08
Job 6	0.00	0.00	0.96	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00
Job 7	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Job 8	0.79	0.94	1.00	0.52	0.80	1.00	0.00	0.00	0.33	0.00	0.00	0.38
Job 9	0.66	0.88	1.00	0.40	0.73	1.00	0.00	0.00	0.29	0.00	0.00	0.33

[a]Worker characteristics

Table 25.5 *S* matrix

S	Worker characteristics			Worker requirement			Experience requirement			Occupation-specific information		
Job 1	0.26	1.50	4.63	1.14	4.94	6.89	0.00	0.31	5.17	0.00	1.39	3.90
Job 2	0.24	1.52	5.29	0.00	0.06	4.77	0.00	0.24	3.56	0.00	0.02	2.80
Job 3	0.00	0.16	3.16	0.00	0.65	4.77	0.00	0.00	3.77	0.00	0.00	2.46
Job 4	0.00	0.00	2.49	1.00	3.76	6.27	0.00	0.00	2.40	1.52	5.43	6.71
Job 5	0.49	1.93	5.03	0.00	1.04	4.45	0.00	−0.03	3.82	0.10	2.94	5.41
Job 6	0.00	0.00	3.58	3.43	6.12	7.49	0.00	0.60	4.97	0.00	0.57	3.20
Job 7	0.00	0.00	4.05	0.00	−0.55	2.16	0.00	0.22	4.85	0.00	2.71	5.19
Job 8	3.38	4.68	6.79	0.00	0.58	4.75	0.52	2.16	6.73	0.00	1.57	4.40
Job 9	2.91	4.27	6.54	0.00	0.46	4.55	0.00	0.59	5.53	0.00	0.57	3.01

S	Workforce characteristic			Occupational requirement			ϕ^-			Defuzzification
Job 1	0.00	0.51	3.68	0.00	1.68	6.29	0.28	2.65	4.61	2.34
Job 2	0.00	0.10	3.80	0.00	4.32	7.17	2.65	4.00	5.20	1.84
Job 3	1.69	5.54	7.80	0.00	0.00	3.55	0.01	1.15	2.78	1.42
Job 4	0.00	0.00	3.07	0.00	2.11	6.61	0.30	2.89	4.82	2.08
Job 5	0.00	1.75	6.35	0.00	0.11	4.21	0.02	1.41	3.22	1.73
Job 6	0.00	1.59	5.10	0.00	0.11	3.44	0.10	1.41	2.71	2.14
Job 7	0.00	0.56	4.79	0.00	0.03	3.75	0.01	1.26	2.91	1.12
Job 8	0.39	4.65	7.35	0.00	0.11	3.44	0.10	1.41	2.71	2.65
Job 9	0.00	0.70	4.98	0.00	1.48	6.09	0.26	2.51	4.47	2.22

Table 25.6 *I* matrix

I	Worker characteristics			Worker requirement			Experience requirement			Occupation-specific information		
Job 1	0.10	1.26	2.98	0.00	0.27	1.32	0.00	0.45	3.63	0.00	1.11	3.30
Job 2	0.00	0.38	3.02	0.44	1.24	8.11	0.04	1.66	4.58	0.40	3.98	8.22
Job 3	1.85	2.62	5.53	0.44	2.01	4.58	0.00	1.15	8.31	0.64	4.13	8.23
Job 4	2.96	4.04	8.68	0.00	0.00	1.62	0.48	0.24	5.60	0.00	0.00	0.83
Job 5	0.00	0.41	2.47	0.67	2.42	4.94	0.00	0.00	8.34	0.00	0.33	1.69
Job 6	1.45	3.04	8.61	0.00	0.00	0.80	0.00	0.00	3.82	0.25	2.13	4.10
Job 7	0.92	2.31	8.58	3.00	4.75	8.48	0.00	0.58	2.85	0.00	0.40	2.62
Job 8	0.00	0.00	0.75	0.45	3.06	8.12	0.00	0.00	1.10	0.00	0.97	2.88
Job 9	0.00	0.00	0.93	0.57	3.29	8.14	0.00	0.00	2.57	0.32	2.14	5.19
I	Workforce characteristic			Occupational requirement			ϕ^-			Defuzzification		
Job 1	0.54	2.02	5.29	0.00	0.40	5.15	0.07	0.79	3.48	1.28		
Job 2	0.44	3.47	7.17	0.00	0.00	1.60	0.18	1.40	5.00	2.00		
Job 3	0.00	0.00	0.91	0.00	2.09	5.55	0.52	1.99	5.71	2.55		
Job 4	1.06	4.13	7.18	0.00	0.28	5.12	0.79	1.32	5.00	2.11		
Job 5	0.00	0.95	6.75	0.00	1.60	5.55	0.13	1.01	5.10	1.82		
Job 6	0.00	1.03	4.18	0.00	1.60	5.42	0.32	1.24	4.56	1.84		
Job 7	0.05	1.93	6.88	0.00	1.87	5.55	0.79	2.13	6.04	2.78		
Job 8	0.00	0.12	1.73	0.00	1.60	5.42	0.09	1.04	3.54	1.43		
Job 9	0.00	1.75	6.85	0.00	0.50	5.18	0.15	1.15	4.57	1.75		

Table 25.7 Rank of SIR flows

	$\varphi \succ (A_i)$	Rank	$\varphi{\prec}(A_i)$	Rank	$\varphi_n(A_i)(19)$	Rank	$\varphi_r(A_i)(20)$	Rank
Job 1	2.34	2	1.28	1	1.06	2	0.65	2
Job 2	1.84	6	2.00	6	−0.16	7	0.48	7
Job 3	1.42	8	2.55	8	−1.13	8	0.36	8
Job 4	2.08	5	2.11	7	−0.03	5	0.50	5
Job 5	1.73	7	1.82	4	−0.08	6	0.49	6
Job 6	2.14	4	1.84	5	0.30	4	0.54	4
Job 7	1.12	9	2.78	9	−1.65	9	0.29	9
Job 8	2.65	1	1.43	2	1.22	1	0.65	1
Job 9	2.22	3	1.75	3	0.47	3	0.56	3

Then we calculate the superiority and inferiority of each alternative with respect to each criterion according to preferred generalized criterion type to construct superiority and inferiority matrixes. The *S* matrix and *I* matrix are as Tables 25.5 and 25.6 respectably.

According to results that were obtained by *S* and *I* flow we compute *n* and *r* flows (Table 25.7).

Step 4. Comparing the results of SIR flows.

Both generated ranking based on net flow and relative flow are identical. However, ranking based on relative flow can be more accurate because calculate the effects of positive flow on net flow.

25.7 Conclusions

Job evaluation through comparing the relative similarities and differences in the content of jobs and placing the value of them can provide a framework for planning and establishing a fair payroll structure. The goal of using job evaluation is to determine a hierarchy of positions that is based on the relative contribution of each job to a firm.

Many researchers and practitioners have focused their work on the comparison of jobs in job evaluation function and deployed a wide range of scientific and technical techniques to enhance efficiency and flexibility of the job evaluation and various approaches are available for it's implementation.

We developed job evaluation by using multi criteria decision making in fuzzy environment. The O*Net criteria in 6 category are taken into account to rank the sample of jobs.

In general, job evaluation and it's problems as well as subjective judgement of appraiser are vague and uncertain, and so fuzzy set theory helps to convert DM preferences and judgements into meaningful results by applying linguistic values to measure each criterion with respect to every jobs. In this paper, a multi-criteria group decision making model has been developed based on fuzzy set theory to efficiently deal with the ambiguity of the decision making problems in practical cases to evaluate the jobs and comparing them.

We applied our model in Kashan University to enable this organization to achieve their job evaluation objectives in the human resource practices. Fuzzy SIR is a helpful tool in multi-criteria decision making, in this method two superiority and inferiority flows show that an alternative how can be preferred to another alternatives. Other flows (n flow and r flow) in this method show that which of superiority or inferiority flow is more powerful than another. It makes decision making process more reliable.

By comparing the results of SIR flows, Monitoring and Evaluation Expert, Office of Education is selected as the first in this ranking and registry expert, expert of executive board of faculty member attraction, expert of preparing thesis, expert of alumni, expert of graduate affairs, expert of student transfers, expert of filing and archive, and expert of talented students were the second to ninth respectively in ranking.

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Chapter 26
Venture Capital and Entrepreneurial Innovation: Research on the Data of GEM in China

Qilin Cao, Qiang Zhou and Yingkai Tang

Abstract This paper took GEM companies listed between 2009 and 2011 as example and used 2SLS method to analyze the relation between venture capital institutions and corporate innovation behavior. We found that venture capital institutions generally have no significant effect on GEM companies, while state-owned venture capital institutions are conductive to improvement of enterprise innovation behavior. Besides, if state-owned and non-state venture capital institutions invest in an enterprise at the same time, share holding of venture capital tend to decrease. Thus, the government should invest more to venture capital as well as support the development of private enterprise and foreign venture capital.

Keywords Venture capital institutions · Entrepreneurial innovation · GEM in China

26.1 Introduction

Since 1940s, U.S. venture capital (VCs) has experienced four stages: Introduction stage, Stable growth stage, Rapid growth stage and Rational adjustment stage; and now it is developing steadily. China VCs dates back to the 1980s and has experienced three stages: Rise, Development and Adjustment, and is now tuning towards maturity. It plays an indispensable role in industrial structure changing, economic growth pattern transformation, etc.

As venture capital institutions (VCI) have unparalleled advantages in their own specialization, the large amount of information and funding sources, VCs can not only provide financial gains to investors which is much more than traditional enterprise can provide, but also a huge potential revenue. Therefore, foreign researchers generally believe that Corporate Venturing is a powerful tool to improve the company's ability

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_26,

to innovate and provide long-term value and stock price gains for the enterprise. For example: Microsoft, IBM, and Intel have all adopted this model. Technological innovation is the soul of enterprises and a powerful guarantee for them to maintain sustainable development.

China is a developing country, and VCs development is not mature enough. Based on the enterprise data of GEM companies, firstly, this paper analyze how VCI affect the technological innovation behavior of startup enterprise, and then explore how different VCI (state-owned, private, foreign, etc) affect enterprise technology innovation based on different kind of VCs and investment; Lastly, according to the empirical analysis result, this paper present some constructive suggestions about future development of VCs and entrepreneurial enterprise. Besides, to study how R&D intensity and share holding of VCs investors affect each other, i.e. R&D intensity can affect share holding of VCs investors and vice versa, this paper use simultaneous equation to revise the disadvantages of OLS and use 2SLS to do statistical analysis.

26.2 Review

As modern financial capital aiming at investing in technical enterprise, VCs has been closely related with high-tech industry. Dissertation on the relation between VCs and innovation of companies was issued in the late 1980s, but this field did not arouse scholars' attention until Kortum and Lerner [7] used mathematical model to illustrate it normatively. The idea that VCs can improve the innovation ability of companies is not consistent with theoretical examination. The arguments mainly focus on two perspectives: whether VCs really affect innovation behavior of companies and which is prior between VCs and innovation behavior of companies. These two arguments lead to three theories about the relation between VCs and innovation behavior of companies: VCs is conductive to technical innovation of companies; VCs and the innovation of companies are not related and VCs hampers the innovation of companies.

In terms of the first theory, it is supported by most scholars. If professional investment institutions dedicate to investing in tech SMEs, it can narrow the funding gap in science and technology enterprises in some degree. Moreover, with strong regulatory capacity of VCs, the value of those enterprises undetected by the market can be found. Other scholars argue that the inflows from VCs symbolize that the enterprise is qualified, and therefore the enterprises will get help to obtain funds from a third party [1]. In 2000 in their article, Kortum and Lerner demonstrated the relation between VCs and innovation behavior of companies for the first time. they use the data of 20 industries of the United States between 1983 and 1992 and computed the related statistics; and the results show that patent research and development of VCs enterprises is more and faster than enterprises without VCs. Tykova [13] used German data and reached the same conclusion. The European Investment Bank [2] thinks that VCs has made outstanding contributions to promote technological innovation; to solve the problem of employment; to increase exports and to promote regional development. Lerner [8] pointed out that VCs can affect technological innovation strongly, which is an important factor in economic prosperity, but the effect is not a neat system (there are different periods of cyclical changes). Chesbrough [5] chooses the data of multinational companies and numbers of VCI since the 1980s as a base and found that the emerging of VCI and corporate R&D spending has a significant positive correlation.

Domestic researches show that VCs has promoted the transformation of the mode of enterprise technology innovation. Wan and Yuan [14] used the Cointegration Theory, which was put forward by Engle and Granger in 1978, to study the relationship between technological innovation and investment industry development and found that VCs time series and the patent time series were non-stationary. The authors therefore hold that VCs can indeed promote innovation. Guo [4] studied how VCI affect enterprise based on traditional principal-agent model; and shifted to a multidisciplinary theory, which emphases on mutual trust and cooperation. Besides, he also studied the impact of different cooperative performance. Yang and Shao [15] did empirical analysis about the causality of VCs and innovation of 24 provinces and autonomous regions between 1997 and 2008, they found that VCs and patent licensing variable is steadily correlated and that the hypothesis of "VCs is prior to innovation" is correct. Through personal interview and questionnaire, Long and Shi [10] found that VCs can improve the technological enterprise's ability to get knowledge both static and dynamic, and then affect high-tech enterprise innovation, improve enterprise performance and decrease innovation risk.

Second, there is no obvious correlation between VCs and entrepreneurial enterprises. Engel and Keilbach took the 1995–2000 data of Germany market as sample, and adopted the method of paring samples to study how VCs affect innovative behavior of the corporate level [3]. Peneder [11] introduced propensity score matching method to control the difference in industry of the study sample, geography, legal environment, credit proportion and innovative behavior. Using Australian data, he found that increasing of VCs number has no influence on the output of enterprise innovation. Finally, VCs has an adverse impact on the enterprise technology innovation, and some relative academic explanations can be found. After VCs joining the enterprise, some entrepreneurs have to give up part of the shares and even controlling power of enterprises, the separation of innovative main detachment and enterprise leads to decreasing of innovation capacity [12]. Zucker et al. [17] studied the relation between VCs and the number of science and technology enterprise. He chose a sample consisting of 327 "Star" companies in biotechnology industry which was wildly used by worldwide scholars. The results showed that the size of VCs market is negatively correlated with the number of start-up companies in the biotechnology industry, and that VCs inhibit innovation in the industry.

From the above analysis, although there are three differences about how VCs affect enterprise technology innovation, most scholars still hold that VCs can promote enterprise technology innovation. The three points may focus on differences in visual analysis, target selection, and empirical data, so they are not directly comparable.

26.3 Variable Selection, Research Methods and Sources of Research Data

26.3.1 Illustration of Endogenous Variable Selection

1. Indicators to measure enterprise technology innovation

Enterprise technology innovation can be measured by multiple indicators. There are four general statements: indicators of innovation activities evaluation, innovation output capacity indicator, innovation and technical resources indicator and innovative technology environment indicator. Generally speaking, R&D expenditure of innovation activities indicator and the number of innovative patents indicator are prior than the rest two because they are more comprehensive and scientific. However, disclosure of each enterprise in the number of patents indicator varies greatly for that data is incomplete and no uniform evaluation system exists. This article therefore use the R&D intensity indicator (R&D expenditures/sales revenue) to measure the technology innovation behavior of enterprises.

2. Indicators to measure the VCs activities

VCs will hold some stake after they join the start-up companies. In this article, we select stake of VCs in companies listed on the Shenzhen Stock Exchange GEM a quarter in the pre-trade as an indicator to measure VCs activities.

26.3.2 Research Method

Considering the bidirectional impact of corporate R&D strength and the stake of venture capitalists, i.e. R&D intensity will affect the stake of venture capitalists, and vice versa, simple methods such as least squares (OLS) cannot solve this two-way problem, so we use the simultaneous equation method instead, in which the parameter estimation method will use a two-stage least squares (2SLS).

In order to test whether VCs can positively affect enterprise technology innovation, we have established the following simultaneous equations Model 1, corporate R&D intensity (research) and stake of venture capitalists (share) are endogenous variables; other corporate financial evaluation indicators are exogenous variables.

$$\text{Research}_{it} = \alpha_0 + \alpha_1 \text{Total}_{it} + \alpha_2 \text{Cash}_{it} + \varepsilon_{it}, \tag{26.1}$$

$$\text{Total}_{it} = \beta_0 + \beta_1 \text{Research}_{it} + \beta_2 \text{Earning}_{it} + \beta_3 \text{Stock}_{it} + \varepsilon_{it}. \tag{26.2}$$

Note: Research_{it} represents the R&D intensity of Company "I". With the different listing time of different enterprises, mere provision of a time zone might cause the research bias, so we select the relevant data for the end of the listing previous year.

- Total_{it} represents the stake of all venture capitalists at the listing time.
- Cash_{it} represents the ratio of operating cash flows and operating revenue in the previous year of GEM listed company "I".
- Earning_{it} represents the earnings per share for the previous year before the stock issue.
- Stock_{it} represents the net assets per share for the previous year before the stock issue.
- ε_{it} represents the Random interference term, represents the number of IPO years, $(i = 0, 1, 2)$, are a coefficient.

Equation (26.1) is to test how the stake of venture capitalists affect corporate R&D intensity of all GEM listed companies in the end of 2011. We believe that corporate R&D intensity is a function of the stake of venture capitalists and corporate cash flows. Equation (26.2) is to test how corporate R&D intensity affect the stake of venture capitalists. The stake of venture capitalists is not only affected by the corporate R&D intensity, but also earnings per share and net assets per share.

As different VCI may affect technology innovation behavior differently, in this study, the case of VC-backed companies is classified into four major categories: Only supported by state-owned VCI, only supported by private VCI, supported by both state-owned and private VCI, and supported by single or mixed other types of VCI. Based on the above analysis, we have established the following four models to analyze the impact of VCI of the different nature of property rights on enterprise technology innovation:

Model 2: Only state-owned VCI into the enterprise.

$$\text{Research}_{it} = \alpha_0 + \alpha_1 \text{State}_{it} + \alpha_2 \text{Cash}_{it} + \varepsilon_{it}, \tag{26.3}$$

$$\text{State}_{it} = \beta_0 + \beta_1 \text{Research}_{it} + \beta_2 \text{Earning}_{it} + \beta_3 \text{Stock}_{it} + \varepsilon_{it}. \tag{26.4}$$

Model 3: Only private VCI into enterprises.

$$\text{Research}_{it} = \alpha_0 + \alpha_1 \text{Private}_{it} + \alpha_2 \text{Cash}_{it} + \varepsilon_{it}, \tag{26.5}$$

$$\text{Private}_{it} = \beta_0 + \beta_1 \text{Research}_{it} + \beta_2 \text{Earning}_{it} + \beta_3 \text{Stock}_{it} + \varepsilon_{it}. \tag{26.6}$$

Model 4: State-owned and private VCI into the enterprise at the same time.

$$\text{Research}_{it} = \alpha_0 + \alpha_1 S\&P_{it} + \alpha_2 \text{Cash}_{it} + \varepsilon_{it}, \tag{26.7}$$

$$S\&P_{it} = \beta_0 + \beta_1 \text{Research}_{it} + \beta_2 \text{Earning}_{it} + \beta_3 \text{Stock}_{it} + \varepsilon_{it}. \tag{26.8}$$

Model 5: Other types of VCI into enterprises.

$$\text{Research}_{it} = \alpha_0 + \alpha_1 \text{Others}_{it} + \alpha_2 \text{Cash}_{it} + \varepsilon_{it}, \tag{26.9}$$

$$\text{Others}_{it} = \beta_0 + \beta_1 \text{Research}_{it} + \beta_2 \text{Earning}_{it} + \beta_3 \text{Stock}_{it} + \varepsilon_{it}, \tag{26.10}$$

where $State_{it}$ represents the stake when only state-owned venture capital institutions into the enterprise, $Private_{it}$ represents the stake when only private venture capital institutions into enterprises, $S\&P_{it}$ represents the total of stake when State-owned and private venture capital institutions into the enterprise at the same time, $Others_{it}$ represents the total of stake when other types of venture capital institutions into enterprises.

Other definitions of endogenous variables or exogenous variables are the same as Model 1.

26.3.3 Sources of Research Data

In this article, we choose the 281 companies listed on Shenzhen Stock Exchange GEM from 2009 to the end of 2011 as sample, including 159 enterprises supported by VCI, take up 56.58 % of the total sample. The name, the nature and the pre-IPO stake of the VCI all come from Qing dynasties Group Zero2IPO China VCs Database and the company's prospectus. Financial data of listed companies (earnings per share, net assets per share, cash flow from operations, research and development expenditures) are from the prospectus. In order to speak with one voice, to avoid changes in assets before and after the listing of the company, the financial data were chosen the relevant data for the end of the listing previous year.

26.4 Empirical Analysis

26.4.1 Descriptive Statistics

Table 26.1 shows two endogenous variables about whether VCI support the companies and three exogenous variables the comparative analysis of the mean, median, maximum, minimum, standard deviation of three exogenous variables which related to the simultaneous equations in this study. The number of samples 159 represents the numerical characteristics of the relevant indicators of the 159 listed companies supported by VCI; The number of samples 122 represents the numerical characteristics of the relevant indicators of the 122 listed companies not supported by VCI; The number of samples 281 represents the numerical characteristics of the relevant indicators of all GEM listed companies by the end of 2011. From the endogenous variables—R&D intensity, the average R&D intensity of VC-backed companies is 5.56 %, which is larger than the average R&D intensity of no VC-backed companies; The highest R&D intensity of VC-backed companies has reached 28.27 %, which is much larger than 22.51 %—the highest R&D intensity of no VC-backed companies. This indicates that the addition of VCs has improved the R&D intensity of companies. From the analysis of the exogenous variables—earnings per share, we found

Table 26.1 Descriptive statistics of the endogenous variables and exogenous variables

Variables	Number of samples	Average	Median	Maximum	Minimum	Standard deviation
Venture stake	159	14.26	11.85	60.96	0.06	9.85
(%)	122	/	/	/	/	/
(Total)	281	/	/	/	/	/
	159	0.79	0.72	2.37	0.27	0.34
EPS	122	0.77	0.70	1.9	0.22	0.34
	281	0.78	0.70	2.37	0.22	0.34
	159	2.93	2.82	6.03	0.52	0.96
Net asset/share	122	2.83	2.57	11.67	0.57	1.41
	281	2.89	2.72	11.67	0.52	1.18
Operating	159	20.27	14.79	117.60	−14.30	21.96
Cash flows	122	18.93	15.46	101.38	−14.93	18.66
(%)	281	19.36	15.06	117.60	−14.93	20.02
R&D intensity	159	5.56	4.26	28.27	0.29	4.43
(%)	122	5.50	4.70	22.51	0.28	3.46
	281	5.53	4.52	28.27	0.28	4.03

Table 26.2 Stake of venture capital institutions with different property rights

Property rights	Number of samples	Average (%)	Median (%)	Maximum (%)	Minimum (%)	Standard (%)
Total	159	14.26	11.85	60.96	0.06	9.85
State	68	10.93	7.76	26.69	0.06	7.63
Private	32	11.74	9.49	38.58	2.5	7.79
S&P	40	18.72	15	60.96	4.9	12.44
Others	19	19.49	19.49	34.39	7.5	8.56

that the addition of VCs has little influence on earnings per share, which are showed as 0.79, 0.77 respectively. The average and the median of net assets per share of the 159 VC-backed companies is 2.93 and 2.82, which is significantly higher than the corresponding indicators of the no VC-backed companies; The average operating cash flows of the VC-backed companies has reached 20.27 %, which is 1.3 % high than the average operating cash flows of the no VC-backed companies. This indicates that from the view of the descriptive statistics, the addition of the VCs has greatly promoted the net assets per share, operating cash flows in the companies.

According to the different scenarios for VCI to support companies, we classified them into four types: supported by state-owned VCs, supported by private VCs, supported by both state-owned and private VCs and other cases; the sample number is 68, 32, 40, and 19 respectively. From the Table 26.2, we can see the average VCs s holding is 14.26 %, which is not too large, because it relates to the business philosophy that put emphasis on return on investment rather than on getting controlling power of enterprise. Private VCI are developing and growing rapidly, especially the GEM listed companies in 2011, most of them are supported by

Table 26.3 Stake of venture capital institutions with different property rights

Variances	Equation (26.1)	Equation (26.2)
C	0.061*** (2.91)	21.269*** (4.62)
Total	0.0011 (0.86)	
Cash	0.053*** (3.08)	
Research		−72.722(−1.12)
Earning		−8.651*** (−2.88)
Asset		1.403
Adj R^2		(1.31)
D.W.	0.014	−0.071
Number of samples	1.75	1.76
	154	154

Note the corresponding figure of each variable is the regression coefficient, brackets for the T statistics, ***,** ,* respectively in confidence level of 1, 5, 10 % are remarkable

private VCs. Companies that supported only by private VCs accounted for 42.8 % of the total samples, close to half. VCs stake of companies with foreign background is also relatively high, reaches 19.49 %, and relatively concentrated. Average stake of companies supported by both state-owned and private VCs is as high as 18.72 %, the maximum even reaches 60.96 %, which makesit become the controlling shareholder, but still relatively dispersed when compared to foreign background venture capital institutions VCI rend of the future development of VCI, for its number has reached over 100 and its stake is relatively concentrated.

26.4.2 The Empirical Results and Analysis

Table 26.3 gives the regression results based on 2SLS method of R&D intensity and VCI stake in model1A that VCI do not have a significant positive impact on corporate innovation behavior. The conclusion is consistent with the study by Kochhar [6] and Zhao [16]. The main reason is that the development period of VCI in China is still short, so the problem of inadequate incentive and restraint exists. The information acquired from the enterprise is not accurate caused the information asymmetry. The coefficient of operating cash flow is 0.053 and the statistical value of T is 3.08, indicating that at the confidence level of 1 %, the cash flow has positive effects on their innovative behavior. In model 1B, the statistics value of T, i.e. R&D intensity, is −1.22, did not show a significant effect on the investment institutions. Earnings per share in the confidence level of 1 % is significant, which shows that corporate profitability has a negative effect on the stake of venture capital institutions, the same conclusion with Liu et al. [9]. This phenomenon may be caused by corporate profitability too strong, and venture capital agencies consider that enterprise development potential is not great enough, more inclined to invest those startups.

Table 26.4 shows how the different nature of property rights of VCI works as a factor in the innovation behavior of GEM enterprise. The Eqs. (26.3–26.9) indicates that, enterprises which are only supported by state-owned VCI have a positive and remarkable regression coefficient, which shows a positive influence towards the innovation of enterprises. In the other three scenario, which is, only supported by VCI, supported by both private and state-owned or supported by foreign or joint venture, changes of the stake of VCI do not significantly affect innovation. Based on this phenomenon, we believe the following reasons:

1. The state-owned VCI, which are considerable more mature and more discreet in choosing which company to invest, is the precursor who invests the start-up enterprises and bring them affluent capital.
2. Though experienced, state-owned venture institutions based on the principles of the "maintain and increase the value", which is far from the private venture capital company's pursuit of high return from high risks. This obvious difference brings opportunity for the private VCs development, leads to many state-owned VCs to introduce private capital, as well as many private VCs development and growth.
3. Though gradually developed, private venture companies have very limited experience, not to mention the GEM has just opened for a short time, which all together limited its support force on the innovation behavior of corporate. So its support was not affected obviously on the enterprise innovation behavior. However, the flexibility and the originality of private venture institutions will surely in the future act as a positive role in promoting the management of the companies and corporate innovation.
4. Since foreign investment, joint ventures, public-private partnerships all together have a very small numbers, and lack of investment case, those data selected above is not necessarily representative. Table 26.4, Eqs. (26.4–26.10) shows the outcome that how business R&D intensity affects the different property right held by venture institutions. Only supported by both state-owned and private, the company has an explicit R&D intensity coefficient, −186.59. That implies the increase of R&D spending will result in reducing the proportion of the total stake of state-owned and private VCI. In short, the company R&D level would in turn affect the proportion of shares of the VCI. Other cases no such pattern can be observed.

26.5 The Research Conclusion and Policy Recommendations

1. The Research Conclusion In this article, we selected 281 companies (159 companies are supported by VCs, excluding the 5 companies which have no R&D intensity indicators, 154 companies in total) listed on Shenzhen Stock Exchange GEM from 2009 to the end of 2011 as sample, and use 2SLS method to analyze how the stake of VCI affect R&D intensity of listed companies. It is proved that China VCI generally have no significant effect on GEM listed companies.

Table 26.4 The simultaneous equations regression analysis of different property rights of venture capital institutions stake and R&D intensity

Variances	Equation (26.3)	Equation (26.4)	Equation (26.5)	Equation (26.6)	Equation (26.7)	Equation (26.8)	Equation (26.9)	Equation (26.10)
C	−0.155 (−0.86)	16.587*** (4.03)	0.089* (1.82)	8.786* (1.63)	0.031 (1.45)	34.753*** (2.92)	−0.025 (−0.15)	5.083 (0.15)
State	0.013* (1.72)							
Private			−0.00397 (−0.96)					
S&P					0.00036 (0.40)			
Others							0.00424 (0.54)	
Cash	0.528** (2.56)		0.065** (2.00)		0.092*** (3.78)		−0.00316 (−0.04)	
Research		1.895 (0.25)		22.564 (0.28)		−186.59* (−1.80)		224.38 (0.57)
Earning		−18.687*** (−3.10)		−4.491 (−1.27)		−20.736** (−2.6)		3.455 (0.17)
Asset		2.942* (1.93)		1.898 (1.37)		3.874 (1.19)		
Adj R^2	0.142	0.246	−0.182	−0.065	0.335	−0.124	0.057	−1.792
D.W.	2.03	2.21	1.77	1.80	1.25	1.84	2.79	2.82
Number of samples	29	29	66	66	40	40	19	19

Note the corresponding figure of each variable is the regression coefficient, brackets for the T statistics, ***, **, * respectively in confidence level of 1, 5, 10 % are remarkable

Additionally, based on the different kind of property rights of VCI, we classified the companies into four groups: those supported by state-owned VCs alone, those supported by private VCs alone, those supported by both state-owned and private VCs and those supported by foreign capital, joint ventures, public-private partnerships, etc. It is also proved that the stake of the state-owned VCI have a significant positive effect on corporate innovation behavior, while other types of VCs has no such effect.

Besides, in this article, we found that R&D spending has a negative effect on the stake of VCI. The empirical results show that corporate R&D intensity has no significant effect on the stake of VCI in general. In the situation that companies are supported by both state-owned and private VCs, the corporate R&D intensity has a negative effect on the stake of VCI, which means that the corporate innovation behavior can affect the shareholding decision of VCs in turn.

2. Policy Recommendation

The VCs in China has developed for no more than 20 years, and it is now turning toward maturity. VCI has enriched experience of investment and management, which can significantly affect corporate innovation and sustainable development. (1) Develop VCs in China vigorously, because VCs has no negative effect on the corporate innovation in general. (2) While developing the state-owned VCI, we should pay more attention to the transformation of state-owned VCI into private VCI. (3) Foreign and joint venture has adequate international and multinational investment experience, thus we can relax the limits and introduce more foreign and joint venture to support the international companies in China.

Acknowledgments This research was supported by the National Natural Science Fund of China (71072066) and the Fund of Sichuan University (SKQY201225, 2013JCPT006).

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Chapter 27
Employee's Perception of Occupational Hazards and Health Complaints in the Financial Sector (Portuguese Sample)

José Miquel Cabeças and Mário Rui Mota

Abstract The research intention of the paper is to identify relevant occupational hazards at workplace level from the financial sector in Portugal and negative mental or physical well-being complaints (5,000 financial service employees/906 respondents). The identification of groups, subgroups and types of hazards, as for example, inadequate working postures (recognized by 65 % of the respondents), long term sitting jobs (99 %), activities with repetitive hand or arm movements (50 %), long or unsociable hours (9–12 h/day) (53 %), career stagnation and uncertainty (49 %), unfair treatment of employees (43 %) and under use of skills (41 %) resulted from the research. Individual physical/somatic complaints, related or aggravated by the work were mentioned by the respondents: low back pain (50 %), neck/shoulder pain (46 %), irritated or allergies in the eyes, nose, throat (40 %), upper limbs pain (37 %), headache, dizziness (36 %) and overweight (obesity) or other dietary problems (16 %). Anxiety (49 %), concentration difficulties (42 %), depression or reduced self-esteem (20 %), suicidal ideation or suicide attempt (3 %) and other mental related complaints were also mentioned by the respondents. The results of this research, according to the employees' perception, may drive the action plans of the professionals (engineers, hygienists, managers) involved in performance improvement activities in the financial sector.

Keywords Occupational hazards · Health complaints · Financial sector · Negative well-being · Work-related disease

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_27,

27.1 Introduction

A 1985 report of a World Health Organization Expert Committee concluded that adverse occupational psychosocial factors have become increasingly important in responses and psychosomatic disease causation. Ample evidence shows that a relation exists between certain types of working conditions and behavioral and psychosomatic disorders among workers.

There is a reasonable consensus in the literature of the nature of psychosocial hazards. Psychosocial risks, work-related stress, violence, harassment, bullying (or mobbing) are recognized major challenges to occupational health and safety [13]. A WHO review [18] collates evidence across all WHO regions on exposures to selected psychosocial risk factors (where available), including job control and demand, work organization, working hours, and relative risks for major health outcomes, including coronary heart disease, depression, and back pain.

It has long been known that negative emotions are related to a higher prevalence of disease. The functioning of the immune system likes to be an important physiological factor in the relationship between positive emotions and health [7, 10, 11, 16, 19, 21]. Positive mood has also been shown to influence the cardiovascular response to stress; prolonged reactivity to stress is harmful to immune function and to other physiological processes.

Robust evidence [20] indicates that many of the most commonly experienced physical effects due to work related stress and psychosocial risks relate to hypertension, heart disease, wound-healing, musculoskeletal disorders, gastro-intestinal disorders, and impaired immune-competence. Disorders usually cited as being stress-related include bronchitis, coronary heart disease [12], mental illness, thyroid disorders, skin diseases, certain types of rheumatoid arthritis, obesity, tuberculosis, headaches and migraine, peptic ulcers and ulcerative colitis, and diabetes.

Psychosocial working conditions may have a detrimental impact on both affective and cognitive outcomes, namely anxiety, depression, distress and burnout [8]. Depression is one of the leading causes of disability and is projected by the WHO to become the second leading cause of the global burden of disease by 2020. Exposure to psychosocial risks has been linked to a wide array of unhealthy behaviors such as physical inactivity, excessive drinking and smoking, poor diet and sleep [8].

The etiology of coronary heart disease (CHD) may include type A behavior, stressful life events, lack of social support, shift work and a sedentary lifestyle [17]. The evidence on the relationship between work-related psychosocial factors and the development of ischemic heart disease (IHD) has been increasing [20].

The metabolic syndrome is a cluster of risk factors that increases the risk of heart disease and type 2 diabetes [6]. Depressive symptoms and severity of stressful life events were associated with the cumulative prevalence of the metabolic syndrome [22].

Evidence from the Whitehall II study ($n = 5{,}895$) has indicated that psychosocial work stress was an independent predictor of type 2 diabetes among women after a 15-year follow-up (period 1991–2004) [15].

27.2 Materials and Methods

The total number of workers in the financial services in Portugal, based on 2011 data (NACE code K64—Financial service activities, except insurance and pension funding; data based on 33 financial institutions associated to the APB—Portuguese Banking Association) [1] were 55,485 workers, 54 % male workers, 55 % aged 30–44 years old and 35 % aged 45 years old or more, 41 % working for more than 15 years in the same institution and 36 % between 6–15 years (included), 97 % with a permanent contract, 52 % with university education/college degree and 48 % with a high school degree or lower.

The method used in the research was based on the application of an on line survey Google Drive/Forms to 5,000 financial service employees (906 respondents) between July/August 2013. Two main groups of questions were mentioned in the questionnaire:
(1) questions related to the occurrence of specific negative well-being hazards;
(2) questions related to individual physical/somatic or mental complaints, related or aggravated by the work.

27.3 Results

Regarding the survey respondents ($n = 906$ respondents), 56 % of the respondents were male workers, 73 % aged 31–50 years old and 19 % aged 51–60 years old, 14 % working between 6–10 years in the same institution, 40 % between 11–20 years, 23 % between 21–30 years, 55 % with university/college degree, 56 % of the respondents worked in direct contact with the clients (front-office), 35 % with administrative or management functions in the central services of the institutions and 9 % with administrative or management back-office functions related with commercial activity, 58 % worked in the last year at the districts of Lisboa, Setúbal and Santarém capital city area, 22 % in the north geographic area and 13 % in the center area of Portugal. Regarding the functions developed by the respondents in their financial institutions, 34 % serving customers at the counter or administrative functions (without technical functions), 24 % heads of department, 38 % with specific functions/jobs and 4 % with ancillary functions/jobs.

Regarding working time related variables, the following results were achieved by the questionnaire ($n = 906$ respondents):

1. 46 % of the respondents worked 7–8 h daily in the financial institution, 46 % between 9–10 h and 6 % between 11–12 h;
2. 15 % of the respondents worked 1–2 days per month during Saturday, Sunday or holiday time (beyond the contracted working time) and 3 % worked 3 or more days per month;
3. 69 % of the respondents spent 1 h or less in the travel time to work (round trip), 25 % spent 1–2 h and 6 % spent more than 2 h travelling to work.

Table 27.1 Percentage of workers from financial institutions who reported somatic/psychosomatic complaints ($n = 906$)

Somatic/psychosomatic complaint	Percentage of employees
Visual acuity loss, visual fatigue, pain in the eyes, difficulty refocusing the eyes	53
Low back pain	50
Neck/shoulder pain	46
Temporary physical fatigue symptoms	43
Dry, irritated or allergies in the eyes, nose, throat	40
Upper limb pain (hand, wrist, forearm, arm)	37
Headache, dizziness	36
Frequent cold, asthma or other respiratory problems	33
Overweight (obesity) or other dietary problems	16
Hypertension or other circulatory related diseases	15
Skin allergies or other skin problems	11
Gastro-intestinal disorders	11
Cardiovascular diseases	6
Symptoms/problems in the urinary tract and reproductive organs	4
Impaired immune-competence or bad general health	3
Hormone related disorders, diabetes or other metabolic problems	3

Regarding psychosocial working related variables, 8 % of the employees considered the relationship with superior poor (7 %) or very poor (1 %); 3 % considered the interpersonal relation with colleagues, poor or very poor; 35 % recognized conflicting demands of work and home [conciliation between work and social/family life poor (31 %) or very poor (4 %)].

Regarding interpersonal relationships at work, particularly workers abuse related variables, 22 % of the respondents reported physical or verbal abuse by colleagues or clients; 20 % reported being discriminated (by any reason), 20 % reported being victim of bullying or mobbing, 5 % reported disrespected to private property (e-mail or lockers violation) and 2 % reported sexual harassment at the work place.

A group of questions were mentioned in the questionnaire, with the objective to identify somatic/psychosomatic complaints directly related or aggravated by the working conditions, according to the perception of the employees. The list of somatic/psychosomatic complaints mentioned in the questionnaire was established with the participation and supervision of an occupational physician from a financial institution, based on his personal experience of dealing with banking workers. The results of this particular group of questions are mentioned in Table 27.1.

A different group of questions were mentioned in the questionnaire, with the objective to identify mental/psychological/social complaints directly related or aggravated by the working conditions, according to the perception of the employees. The list of mental/psychological/social complaints mentioned in the questionnaire was also established with the participation and supervision of an occupational physician from a financial institution, based on his personal experience of dealing with

Table 27.2 Percentage of workers from financial institutions who reported mental/psychological /social complaint ($n = 906$)

Mental/psychological/social complaint	Percentage of employees
Anxiety	49
Concentration difficulties	42
Irritability or hostility	34
Negative well-being, dissatisfaction, reduced quality of life	28
Sleep or sexual disorders	21
Depression or reduced self-esteem	20
Family and social relationships degradation	17
Dependence on smoking, drinking, drugs or psychotropic substances	12
Chronic fatigue/burnout	8
Other psychological/mental signs or symptoms not referred	5
Suicidal ideation or suicide attempt	3

banking workers. The results of this particular group of questions are mentioned in Table 27.2.

The hazards or risk factors taxonomy developed by Cabeças [2–5] is presented in a Risk Factors-Disorders Matrix, organized in a three levels structure: groups, subgroups and types of hazards. Fourteen groups of hazards are proposed in the first level of the Risk Factors-Disorders Matrix: (1) Mechanical; (2) Thermal; (3) Electrical; (4) Radiations; (5) Noise; (6) Vibrations; (7) Chemical; (8) Biological; (9) In the work environment; (10) Musculoskeletal; (11) Psychosocial; (12) Individual; (13) Emerging; (14) Other hazards. Subgroups of hazards were identified in the second level of the taxonomy and different types of hazards were coded in the third level.

A correspondence was established in the Risk Factors-Disorders Matrix, between each type of hazard and the corresponding potential dominant health disorder. The association establishes indicative and dominant health disorder, as being the type of disorder most frequently referred to in the literature. To some types of hazard, several associations were established to the same type of hazard.

Four types of dominant occupational health disorders were associated to the different types of hazards in the Risk Factors-Disorders Matrix:

1. Occupational injuries, resulting from accidents;
2. Occupational diseases, resulting from the exposure to a causal agent and recognized by the Commission Recommendation 2003/670/EC of 19 September 2003 concerning the European schedule of occupational diseases;
3. Work-related diseases, with multiple causal agents and not included in Annexes I and II of 2003/670/EC;
4. Negative social/behavioral, mental/psychological or physical/somatic well-being, including dissatisfaction and discomfort complaints not directly related to injuries or diseases symptomatology.

This matrix or checklist [2–5] serves as a quasi-exhaustive list of hazards, allowing the safety and health technician to observe the work environment with an extensive checklist of hazards, checking the identified hazards, and questioning systematically all the remaining hazards observed in the matrix.

To characterize specific occupational hazards to negative occupational well-being (not directly related to injuries or diseases symptomatology), three well-being dimensions are proposed in the taxonomy: physical/somatic, mental/psychological and social/behavioral well-being [24] (Table 27.4). Negative physical/somatic well-being (not directly related to injuries or diseases symptomatology) is characterized by physical/somatic discomfort complaints, like generalized tiredness (lack of energy) and localized pain (fatigue related musculoskeletal pain or discomfort). Negative mental/psychological well-being may be characterized, for example, by, displeasure (job dissatisfaction), reduced involvement and activity (low aspiration), anxiety (opposite of contented), low arousal (reactive to stimuli), depressed (opposite of enthusiastic), tiredness (opposite of vigor), demotivation, nervousness, irritability and hostility [23]. Negative social well-being (due to, for example, of bullying, harassment, conflict, physical/psychological violence, poor social relations) may be characterized, for example, by depersonalization towards colleagues, referring to an indifferent and negative attitude towards the people one works with (cynical and detached responses to others), low work engagement (distancing oneself from the object and the content of one's work, vigor, dedication), loss of self-esteem, defenselessness, negative affect (subjective distress subsuming a broad range of aversive mood states such as anger, disgust, scorn, guilt, fearfulness [9]), reduced commitment and involvement, workplace jealousy and envy amongst employees.

The answers from the financial institutions workers to questions related to the occurrence of specific negative well-being hazards were organized in the Risk Factors-Disorders Matrix.

Based on evidences from the literature, a correspondence may be established in the Negative Well-Being Matrix (Table 27.3), between each type of hazard and work related diseases. To some types of hazards, two associations may be established; some hazards may cause a work related disease or a discomfort complaints and dissatisfaction, depending on the exposition, intensity and multiple individual and environmental factors.

In order to better evaluate the importance of the different negative well-being hazards identified in the financial institutions, the hazards mentioned in Table 27.3 will be ordered by the percentage of workers that recognized the presence of the hazard in the work place (% of respondents).

27.4 Results and Discussion

The results presented in Table 27.4, revealed a group of hazards particularly recognized by the financial institutions workers, promoting negative occupational well-being and contributing to the existence of work related diseases among those

Table 27.3 Relevant negative well-being hazards (negative well-being matrix), adapted and developed from the risk factors-disorders matrix [2–5]

Sub-group of hazard	Code	Type of hazard	Percentage of resp.
5.1 Noise	5.1.3	Disturbing noise	15[a]
9.1 Indoors climate	9.1.1	Indoors thermal discomfort (cold or hot temperature)	21
	9.1.2	Indoors humidity discomfort (wet or dry humidity)	20
9.2 Indoor ventilation (natural or mechanical)	9.2.2	Inadequate location/direction of air flow	13[a]
9.3 Work area lighting	9.3.1	Illuminance or light level (light intensity in a work area)	22[a]
9.4 Physical layout	9.4.1	Open workplaces (offices)	33[b]
10.1 Force	10.1.1	Lifting loads or moving people activities; carrying or moving (particularly packs with coins)	2[a]
10.2 Repetition	10.1.2	Activities with repetitive hand or arm movements (handling and counting banknotes)	50[a]
10.3 Postures	10.1.3	Inadequate working postures	65[b]
10.4 PC work	10.1.4	Working regularly with computers (ergonomic inadequacy)	33[b]
10.5 Standing, sitting	10.1.5	Long term sitting jobs	99[a]
11.1 Job content	11.1.1	Lack of variety (monotonous)	15[a]
	11.1.2	Meaningless work	8[a]
	11.1.3	Under use of skills	41[a]
	11.1.5	Continuous exposure to clients through work (dealing with customers face to face)	56[a]
11.2 Workload, work pace	11.2.1	Continually subjected to deadlines	23[a]
	11.2.2	Work overload	35[a]
	11.2.4	Insufficient working breaks	30[a]
	11.2.5	High levels of time pressure	26[a]
11.3 Work schedule	11.3.4	Long or unsociable hours (9–12 h/day)	53[a]
11.4 Control	11.4.1	Low participation in decision making (job influence)	34[a]
	11.4.2	Lack of control over workload, pacing	15[a]
11.5 Organizational culture and function	11.5.1	Poor communication (with colleagues and with hierarchy)	28[a]
	11.5.3	Lack of definition on organizational objectives	20[a]
	11.5.4	Unfair treatment of employees (performance evaluation and feedback, career development, etc.)	43[a]

Continued

Table 27.3 Continued

Sub-group of hazard	Code	Type of hazard	Percentage of resp.
11.6 Interpersonal relationships at work	11.6.2	Poor relationships with superiors	8[b]
	11.6.3	Interpersonal conflict	3[b]
	11.6.4	Lack of social support (by the institution)	18[a]
	11.6.5	Bullying or mobbing	20[c]
	11.6.6	Harassment (sexual)	2[c]
	11.6.7	Discrimination	20[c]
	11.6.8	Disrespected to private property	5[c]
	11.6.9	Physical and verbal violence	22[c]
11.7 Role in organization career development	11.7.2	Poor pay	24[a]
	11.7.3	Career stagnation and uncertainty	49[a]
	11.7.4	Under promotion	28[a]
	11.7.5	Job insecurity	20[a]
11.8 Home-work interface	11.8.1	Conflicting demands of work and home	35[b]

Note [a]Most of the time (many times);
[b]Unpleasant and very unpleasant (incorrect and very incorrect; inadequate and very inadequate);
[c]It happened

workers (according to the literature). The ordered list of occupational hazards mentioned in Table 27.4 are the most frequently referred to by the workers and not necessarily the most hazardous ones. Considering the psychosocial hazards mentioned in Table 27.4, according to the literature, the exposure to most of the hazards are correlated to psychosomatic diseases or mental/psychological diseases (as for example, long or unsociable hours (9–12 h/day), poor communication with colleagues and with hierarchy, high levels of time pressure, physical and verbal violence, bullying and discrimination).

Regarding somatic/psychosomatic complaint directly related or aggravated by the working conditions, according to the perception of the workers, musculoskeletal complaints were referred to by 46–50 % of the respondents and overweight (obesity) or other dietary problems and hypertension or other circulatory related diseases by 15–16 % of the respondents (cardiovascular diseases by 6 % of the respondents).

In the domain of the mental/psychological/social complaint, anxiety, concentration difficulties and irritability/hostility were mentioned by 34–49 % of the respondents. Suicidal ideation or suicide attempt was mentioned by 3 % of the respondents and considered directly related or aggravated by the working conditions, according to the perception of the employees.

The conclusion of the research revealed the importance of maintaining an acceptable level of employees' well-being in order to prevent physical and mental complaints which may directly affect the workers' health and productivity in the financial sector. The negative well-being occupational hazards identified in this

Table 27.4 Negative well-being hazards identified in the financial institutions, ordered by the percentage of respondents who identified the hazards in the work place ($n = 906$) [2–5]

Sub-group of hazard	Code	Type of hazard	Percentage of resp.
10.5 Standing, sitting	10.1.5	Long term sitting jobs	99[a]
10.3 Postures	10.1.3	Inadequate working postures	65[b]
11.1 Job content	11.1.5	Continuous exposure to clients through work	56[a]
11.3 Work schedule	11.3.4	Long or unsociable hours	53[a]
10.2 Repetition	10.1.2	Activities with repetitive hand or arm movements	50[a]
11.7 Role in organization/Career development	11.7.3	Career stagnation and uncertainty	49[a]
11.5 Organizational culture & function	11.5.4	Unfair treatment of employees	43[a]
11.1 Job content	11.1.3	Under use of skills	41[a]
11.2 Workload and work pace	11.2.2	Work overload	35[a]
11.8 Home-work interface	11.8.1	Conflicting demands of work and home	35[b]
11.4 Control	11.4.1	Low participation in decision making	34[a]
9.4 Physical layout	9.4.1	Open workplaces (offices)	33[b]
10.4 PC work	10.1.4	Working regularly with computers	33[b]
11.2 Workload and work pace	11.2.4	Insufficient working breaks	30[a]
11.5 Organizational culture & function	11.5.1	Poor communication	28[a]
11.7 Role in organization/Career development	11.7.4	Under promotion	28[a]
11.2 Workload and work pace	11.2.5	High levels of time pressure	26[a]
11.7 Role in organization/Career development	11.7.2	Poor pay	24[a]
11.2 Workload and work pace	11.2.1	Continually subjected to deadlines	23[a]
9.3 Work area lighting	9.3.1	Illuminance or light level	22[a]
11.6 Interpersonal relationships at work	11.6.9	Physical and verbal violence	22[c]
9.1 Indoors climate	9.1.1	Indoors thermal discomfort (cold, hot)	21
11.5 Organizational culture & function	11.5.3	Lack of definition on organizational objectives	20[a]
11.6 Interpersonal relationships at work	11.6.5	Bullying or mobbing	20[c]
11.7 Role in organization/Career development	11.7.5	Job insecurity	20[a]
11.6 Interpersonal relationships at work	11.6.7	Discrimination	20[c]
9.1 Indoors climate	9.1.2	Indoors humidity discomfort	20
11.6 Interpersonal relationships at work	11.6.4	Lack of social support (by the institution)	18[a]
5.1 Noise	5.1.3	Disturbing noise	15[a]
11.1 Job content	11.1.1	Lack of variety (monotonous)	15[a]

Continued

Table 27.4 Continued

Sub-group of hazard	Code	Type of hazard	Percentage of resp.
11.4 Control	11.4.2	Lack of control over workload, pacing	15[a]
9.2 Indoor ventilation	9.2.2	Inadequate location / direction of air flow	13[a]
11.1 Job content	11.1.2	Meaningless work	8[a]
11.6 Interpersonal relationships at work	11.6.2	Poor relationships with superiors	8[b]
11.6 Interpersonal relationships at work	11.6.8	Disrespected to private property	5[c]
11.6 Interpersonal relationships at work	11.6.3	Interpersonal conflict	3[b]
10.1 Force	10.1.1	Lifting loads or moving people activities; carrying or moving	2[a]
11.6 Interpersonal relationships at work	11.6.6	Harassment (sexual)	2[c]

Note [a]Most of the time (many times);
[b]Unpleasant and very unpleasant (incorrect and very incorrect; inadequate and very inadequate);
[c]It happened

research, according to the employees' perception, may drive the action plans of the professionals (engineers, hygienists, managers) involved in performance improvement activities in the financial sector. The negative well-being hazards listed in Tables 27.3 and 27.4, serves as a list of key hazards in financial institutions (based on a Portuguese sample), allowing the safety and health technician to observe the work environment with an extensive checklist of hazards, checking the identified hazards, and questioning systematically all the remaining hazards observed in the matrix.

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Chapter 28
Research on Construction and Analysis of the Six-Dimension Integrated Strategic Transformation Modeling

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Abstract This study constructs a strategic transformation process mechanism model based on the analysis of literature, and then demonstrates the inter-relation and functions of its elements and influent factors. The study has shown that the motivation driving force, environmental insight, transformational leadership, transformational preparation, transformation implementation, integration of transformation and the relationship between each other are the main factors that influence the strategic transformation. The preparation, implementation and integration of transformation are the core elements of the integrated model while the motivation driving force, environmental insight and transformational leadership are the peripheral factors of the model. The relationship between the core factors and periphery factors is essentially the knowledge creation and communication process between core factors and periphery factors in the strategic transformation.

Keywords Strategic transformation · Process mechanism · Transformation process

28.1 Introduction

With the increasingly fierce competition, customer demand increasingly personalized, enterprises facing lots of issues, such as excessive investment, the impact of the Internet and slow growth in business mode. These issues force the companies to carry on the strategic transformation and integrate to the new direction. For example: China Telecom network operators from a traditional to a modern integrated information service provider, Deutsche Telekom is committed to become a leading global telecommunications industry service company.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_28,

We consider that strategic transformation is one enterprise in order to achieve sustainable development or significant changes in business environment, facing a critical turning point in the management of their own strategies directional adjustment and ensure the effective implementation of the strategy, enabling enterprises to adapt to environmental changes or overcome the process of managing the crisis. In the practice of the enterprise strategic transformation, the systemic and blameless theory system is needed, i.e. what are the important factors that need to be emphasized in strategic transformation and how the process and mechanism of the strategic transformation is. This paper analyzes the complex process of strategic transformation, reveals the process and mechanism of strategic transformation, and expands the strategic transformation of research. Thus, the article intends to be of practical use to managers.

28.2 State of Mass Strategic Transformation Research

The connotation of the strategic transformation has not been clearly defined, more representative of the study: Inorderto survive and prosper, every organization must develop and maintain an acceptable alignment with its environment [8]. Strategic transformation is non-continuous process of organizational development, relative to those of the existing state of fine-tuning, requires senior managers to establish the prospects, to explain to the shareholders [9]. Strategic change is frequently viewed as emanating from the purposeful choices of organizational actors intent on achieving a prespecified goal against a backdrop of existing environmental forces [7].

The motivation functioned as the transition planning and designs, Transition Implementation, Transition integration generate a driving role in the strategic transformation. Therefore the transformation of motivation is important. Kotter and Heskett Mentioned Including the extensive and favorable technological change, international economic integration, developed domestic market saturation and other factors, competition in the market and the main driving force of globalization [4]. Furthermore Boyle and Desai Investigated from 1972 to 1989 between 30 literature identified 24 organizations to promote the transformation of internal and external factors that will be summarized in four categories: internal administrative factors, external strategic factors, internal and external administrative factors, and noted relative changes in the environment within the organization external environment a greater impact on performance, while the internal environment problems arise primarily attributable to management controls are not in place [2].

About elements of the strategic transformation, Levy and Merry Considered strategic transformation is because business problems, in order to survive, you must include the organization's mission objectives, structure, corporate culture, has made significant changes [6]. Bound and Dobbiens pointed out strategic transformation contains the following: (1) Strategic positioning(Including product type, customer characteristics and marketing activities in the geographic area involved) and change in Core expertise (Organizations to establish their competitive advantage needed resources and capabilities); (2) Technology: Enterprise technology, production process equipment, work practices and relevant regulations and policy changes; (3) Structure: Structural changes including changes in the organizational structure, the content of individual job redesign, as well as the rights between the two structural changes; (4) staff: Personnel concept, skill, knowledge, and other changes; (5) Cultural transformation: Members shared values and norms of behavior change [1]. In addition, Ginsberg point out Strategic transformation, including strategic content and strategic decision-making process, the transformation of content for product and market competition policy have changed; Decision-making procedures are included in the transformation of corporate culture, formal management system and (or) in the organizational structure of the transition [3].

Several alternative conceptualizations of Strategic transformation were subsequently offered. Some of them followed an approach closer to the connotation and the motivation, whereas others tended to undertake an approach more akin to element. Next, we present a brief overview of the main alternative conceptualizations (see Table 28.1 for main definitions).

28.3 A Brief Review of Previous Research

Scholars laid the foundation about transformation remains to be further studied, mainly in three aspects: First, research on the transformation of motivation failed to explain the strategic transformation of specific dimensions, not related how to drive strategic motives transformation. The second is based on elements research in the field, without taking into account the relationship between the elements and the transformation of the role of the path, the transformation process as a single process, which is actually contrary. Third, most previous studies using large sample method, you cannot examine in depth the specific process and mechanism of transformation. The shortcomings of previous studies indicated the importance and necessity of this study.

28.4 Strategic Transformation Theories and Model Construction and Analysis

28.4.1 Model of Strategic Transformation Process Mechanism Constructs

Process studies take time seriously, illuminate the role of tensions and contradictions in driving patterns of change, and show how interactions across levels contribute to change [5].

Table 28.1 Main definitions of strategic transformations

Perspective	Study	Definition	Key words
The connotation of strategic transformation	[8]	In order to survive and prosper, every organization must develop and maintain an acceptable alignment with its environment	Environment adjustment
	[9]	Strategic transformation requires senior managers to establish the prospects	Prospects
	[7]	Strategic change is frequently viewed as emanating from the purposeful choices of organizational actors intent on achieving a prespecified goal against a backdrop of existing environmental forces	Organizational actors
The motivation	[4]	Including the extensive and favorable technological change, international economic integration, developed domestic market saturation and other factors, competition in the market and the main driving force of globalization	Technological change, international economic integration, developed domestic market saturation
	[2]	Consider transformation including four categories: internal administrative factors, external strategic factors, internal and external administrative factors, and noted relative changes	Internal administrative factors, external strategic factors, Internal and external administrative factors, noted relative changes
The elements of strategic transformation	[6]	Strategic transformation is because business problems, in order to survive, including the organization's mission objectives, structure, culture, has made significant changes	Organization's mission objectives, structure, culture
	[1]	Strategic transformation contains Strategic positioning, technology, Structure, staff cultural	Strategic positioning, technology, structure, staff cultural
	[3]	Strategic transformation, including strategic content and strategic decision-making process, the transformation of content for product and market competition policy have changed; Decision-making procedures are included in the transformation of corporate culture, formal management system and (or) in the organizational structure of the transition	Product and market competition policy, culture, formal management system, organizational structure

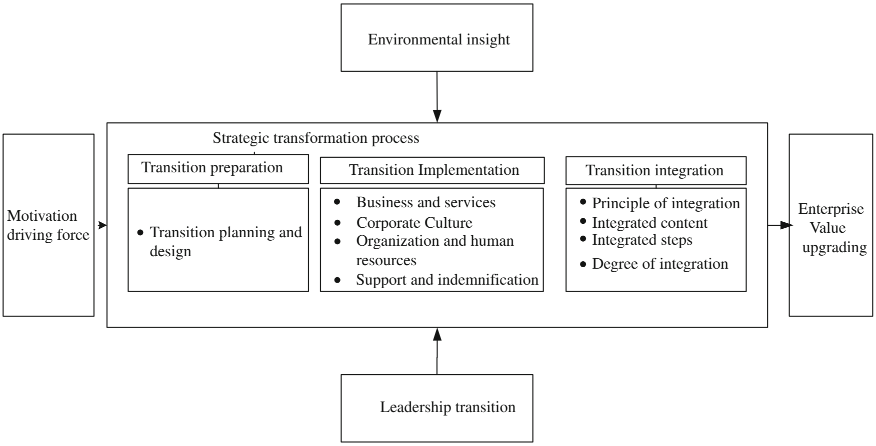

Fig. 28.1 Initial construction of the transformation process mechanism model

Motivation angle studies suggest that internal and external environment, performance pressure, competitive landscape and strategic motivation are the driving factor for strategic transformation. Meanwhile, the process as a series of activities was no difference in the "black box". We can export and transformation by driving the black box motivation to achieve business value added and sustainable development, transformation and motivation is stronger, the greater the driving forces.

Element perspective studies suggest that transformation including environmental insight, organizational vision, business and services, organization and human resources, Corporate Culture, leadership, Management pattern, systems and policies and other factors change. Comprehensive results of previous studies and logical deduction, we can construct a preliminary integrated model of strategic transformation, Fig. 28.1.

28.4.2 The Relationship of Process Mechanism Model Between the Various Dimensions

Strategic transformation is not a single factor alone play, from process mechanism model point of view is driving force motivation, environmental insight, strategic transformation process and other factors combined effects of different degrees of cross contains both mixed. The model emphasizes the transformation of motivation, Strategic transformation process, Leadership Transition three dimensions, which is quite common in the enterprise; environmental insight as a important dimension of transformation, which in actual business transformation activities to be reflected; Finally, the business value integrated into the model, recognizing that Enterprise Value of upgrading in the lead role.

The model emphasizes the correlation between each dimension; these associations are an important guarantee to achieve strategic transformation. First, the motivation driven through transition preparation, transition, implementation and integration of the conduction impact on strategic transformation generates a driving role, the stronger the motivation driving force, the greater effectiveness. Second, the key to success is to adapt to the changing business environment. Through the enterprises are facing opportunities and challenges and policy profound insight, the company can apply to resources; generate a key role for strategic transformation. Third, the transition preparation is ready to focus on transition planning and design, is the strategic direction. By analyzing the internal and external business trends, carry out viable restructuring ideas, transformation principle, the transition path, resource allocation, action plans, and the overall direction of the formation of strategic transformation; Fourth, Transition Implementation is the core of transformation. Culture is the basis for strategic transformation. No change in the concept of culture, strategic transformation is often a lack of thoroughness, culture is inherent in the concept of the strategic transformation of one of the greatest resistance; business and service is the core of strategic transformation, the essence of strategic transformation is reengineering the company's business model; organization and human resources, Support and indemnification is a guarantee of the success of strategic transformation. It will inevitably bring organizational change and resource allocation changes. Similarly, there is no management operations, system construction, resource allocation, support and protection, strategic transformation inevitably fail. Sixth, the transition integration is the key to the success, which focuses on the integration principle, the integration of content, integration steps, and the degree of integration. Strategic transformation is an unprecedented change, the integration throughout the entire process of strategic transformation, transition integration through strategic restructuring; transformation and implementation of the conduction influence on the produces a leading role.

28.4.3 The Interaction of Transformation Process Mechanism Model

The Interaction of the model is the fundamental way to achieve strategic transformation, so the need to explain the association between various factors. Transformation preparation, implementation and integration are core elements; motivation, transition leadership are the model of external factors, the relationship between the core factors and external factors is essentially a strategic transformation of the core factors and external knowledge creation and communication process.

Environmental insight throughout the transition process is the link between internal and external. Motivation angle studies suggest that the internal and external environment, performance pressure, competitive landscape and strategic motivation are the strategic transformation of motivation. Meanwhile, the process as a series of activities was no difference in the "black box". We can export and transformation

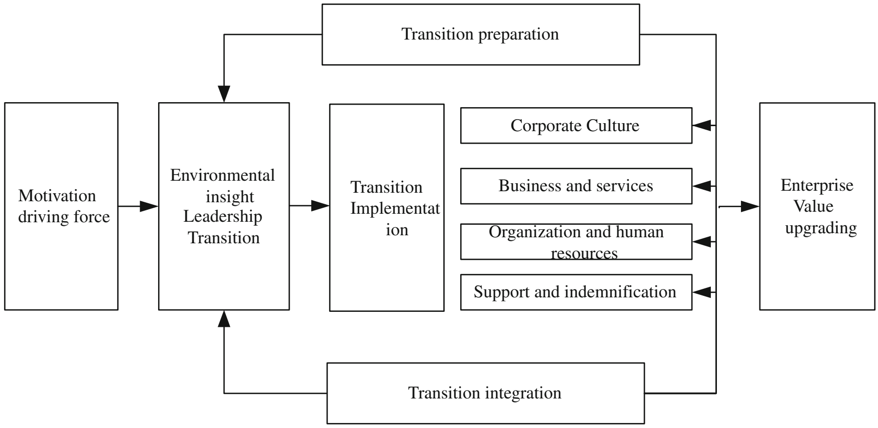

Fig. 28.2 The interaction between the processes mechanism model

by driving the black box motivation, enhance the value of the enterprise and sustainable development, transformation and motivation is stronger, the greater the driving force. Environmental insight enterprises are facing restructuring by first identifying opportunities, challenges and policy environment, generate a key strategic direction of the transformation leading role, followed by environmental insightful decisions for the smooth transition strategy formation, again through the corporate environment insight into the internal and external environment facing on the strategic transformation produces conductivity, making the transition to full deployment, the transition of the project to be fully implemented.

The interaction between the model can be summarized in Fig. 28.2.

28.5 Conclusions and Prospects

This study suggests that the strategic transformation of enterprises in order to achieve sustainable development or reply to big changes in the business environment, management faces key turning point in the case, and the directionality of its own strategy adjustments and ensure the effective implementation of the strategy, enabling enterprises to adapt to environmental changes or overcome business crisis process.

Therefore strategic transformation lies first and foremost motivation for restructuring profound understanding of the formation of the transition direction. On this basis, planning and design of strategic transformation, the overall deployment, mainly in the strategic transformation of vision, meaning, goal setting, strategic transformation initiatives focus formation. The implementation of the new strategy and an inevitable requirement for business-to-business and service transformation, while the corresponding philosophy and culture, organization and manpower, support and security, and with suitable resource optimization and configuration. Through the strategic transformation of the three stages of promotion, enterprise strategic transformation will form a new strategic direction and support system, including: business and services, corporate culture, organizational structure, human resources support, so in order to achieve sustainable development.

Based on the above understanding through research, we draw the following conclusions:

(1) Strategic transformation is a dynamic process, is a long-term nature and complexity of both the systems engineering, not a single factor alone work, motivation in transition, environmental insight, strategic transformation process combined result of various factors.

(2) The success of strategic transformation begins with a deep understanding of motivation in transition. The motivation by driving strategic transformation process, enhance the value of the enterprise and sustainable development, the driveling is stronger, the greater the driving force.

(3) The key lies in Transition Implementation have to seize the environmental insight. Environmental insight enterprises are facing restructuring by identifying opportunities, challenges and policy environment, the formation of the timing and direction of transformation, to enable enterprises to effectively adapt to the external environment and resources.

This research can transition from the strategic framework for enterprise level to provide some reference. This study also has the following disadvantages: (1) the lack of case studies, particularly comparative cross-case analysis; (2) the lack of large sample empirical research. (3) In this paper, the three stages of strategic transformation and each stage of key factors, but for all stages of the transition process to the key factor for effect, Lack of in-depth demonstration.

Based on the above research deficit, further study is available from the following several aspects: (1) for the industry and enterprises comparative case studies; (2) further research to explore how each of these factors affect other factors; (3) to make a general argument, for more business through large sample empirical statistical study, from an empirical point of view of the proposed model for further test.

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Chapter 29
Analysis on Regional Difference in Relationship Between Financial Development and Urban–Rural Income Gap

Limin Yang, Liuliu Kong, Yanni Shen and Yuanyaun Ge

Abstract Using a nonlinear threshold regression model, the paper empirically studied regional difference in relationship between financial development and urban–rural income gap based on Chinese provincial panel data from 1993 to 2011. The result indicates the nonlinear relationships existed in east, middle, and west regions of China. Besides, financial development narrowed urban–rural income gap initially and then widen the gap after a certain financial development level. These relationships were different regionally.

Keywords Financial development · Urban–rural income gap · Threshold regression model

29.1 Introduction

The 12th five-year plan puts forward a major task to adjust income distribution relationship, to balance urban–rural development and promote regional economic interactions. As a connection link among different industries, financial industry plays an important role in regulating income distribution. Thus financial development level will have a certain influence on the residents' income distribution.

Since the opening reformation, economic and financial level developed rapidly in east area of China for the first chance. Middle area, benefited by the nation's follow-up policies of rising middle area, has developed rapidly recently. West area, following the strategy on west development, has also achieved rapid economic development, in spite of weaker natural geographical conditions and social economic base than that of east and middle areas. But now, what is the present situation in these

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_29,

areas about the urban–rural income gap after the policy support? What effects does financial development have on the urban–rural income gap? And are there regional differences? To answer these questions has important practical significance in policy making as well as the performance evaluation of policy implementation.

29.2 Literature Review

At present, the foreign scholars' research findings can be roughly divided into three results. The first is the inverse U shape. Greenwood and Jovanovic [4] found that in the early stage, financial development would wide income gap, but the distribution of income would become equal late. Luo and Gao [7] showed that in the long run, rural finance development had a stable long-run equilibrium with rural income inequality, it was a negative correlation, but in the short term, they had short-term fluctuations in the same direction. The second is beneficial type. Clark et al. [2] used data of 35 years including 91countries to do empirical study for the first time, showing that there is a negative correlation in a long term between financial development and income gap. Beck et al. [1] found that financial development could make the poor benefit more, and had a poverty reducing effect. The last is a harmful type. Maurer and Haber [9] thought that during the financial development, the main beneficiaries were not for the poor but the rich.

The domestic researches began in 2003. Some scholars think financial development would wide the income gap. Yu and Wang [11] empirically researched the relationship between finance and income gap in China in the period from 1978 to 2006, which found that there is close relationship between financial development and income gap in every region of China. Zhang et al. [12] used Chinese data of bank credit and urban–rural income gap from 1978 to 1998 to do empirical research and the results showed that the China's financial development greatly widened income gap. Wen et al. [10] pointed out that Chinese economy is an urban–rural dual structure and empirical result showed that farmers' income had a negative relationship with financial development. Li [6] proved that there is a negative correlation between rural financial development level and urban–rural income gap. There are also supporters of inverted U hypothesis. Fang [3] found that the relationship between financial development and income gap was an inverted U type, based on data from 1978 to 2003. Others thought the relationship is not significant. Lu and Chen [8] showed that the main reason of narrowing the income gap was not the financial development but the improvement of urbanization.

Most literature were based on traditional linear model, ignoring the possible nonlinear relationship and regional differences. This paper empirically researches the topic based on the nonlinear relationship hypothesis between financial development and urban–rural income gap. In the following of the paper, the model, data, and variables are described, then descriptive statistics results and empirical results and analysis are shown, at last conclusion and recommendation are put out.

29.3 Data Source, Variables and Model

29.3.1 Data Source

All raw provincial panel data are from new China's 60-year compilation of statistics, the Statistical Yearbook and the RESSET database. The paper divides China into east (including Beijing, Tianjin, Hebei, Liaoning, shanghai, Jiangsu, Zhejiang, Fujian, Guangdong, Shandong and Hainan), middle (including Jilin, Heilongjiang, Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan) and west (including Guangxi, Sichuan, Chongqing, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang and Inner Mongolia) areas. The paper used agricultural population instead of rural population, and used non-agricultural population instead of urban population. The original data of foreign direct investment are adjusted based on exchange rates, and missing data are obtained by interpolation method. Other data are conversed with benchmark year of 1993.

29.3.2 Variables

There three kind variables in the model are urban–rural income gap, financial development and control variables. They will be described in detail in the following paragraph.

1. Urban–rural income gap, defined as URIG

   This variable was measured by the theil index. The formula is as follow.

$$\text{URIG}_{i,t} = \sum_{j=1}^{2} (Y_{ij,t}/Y_{i,t}) \ln\left(\frac{Y_{ij,t}/Y_{i,t}}{N_{ij,t}/N_{i,t}}\right),$$

where $\text{URIG}_{i,t}$ represents the theil index in year t of i province, $j = 1$ represents rural area, $j = 2$ represents urban area, Y means total income, N represents total population.

2. Financial development

   The paper uses FIR to measure financial development. FIR = financial institutions *deposit and loan balance of region*/GDP of region.

3. Control variables

- Regional economic growth (LnRGDP): measured with logarithm of real GDP per capital.
- Urbanization (URB): measured with the ratio of urban population to total population.
- Financial support agriculture (ARG): measured with the ratio of agricultural expenditure in Fiscal budget spending to Fiscal expenditure.

- Open-door to the outside world (OPEN): measured with the ratio of FDI to regional GDP.
- Dual economic structure (EYJ): measured with the ratio of agricultural comparative labor productivity to non-agricultural comparative labor productivity. The formula is: EYJ = agricultural comparative labor productivity/non-agricultural comparative labor productivity = GDP of the first industry|employment of the first industry/GDP of the second and third industry|employment of the second and the third ndustry.

29.3.3 Model

In this paper, threshold regression model is used to do empirical research. A single threshold model is supposed as follow:

$$\mathrm{URIG}_{it} = \alpha x_{it} + \beta_1 \mathrm{FIR}_{it} I(q_{it} \le \gamma) + \beta_2 \mathrm{FIR}_{it} I(q_{it} > \gamma) + \mu_i + \varepsilon_{it}. \quad (29.1)$$

Among these variables, x_{it} means the control variables, including LnRGDP, URB, ARG, OPEN and EYJ; α is the corresponding coefficient vector; FIR represents the level of financial development; q_{it} is the threshold variable; γ is the specific threshold value; $I()$ is the index function, if the condition in the bracket is satisfied, the result will be $I = 1$, or $I = 0$; μ_i reflects the unobserved individual characteristics; ε_{it} is the random perturbation. In order to obtain parameters' estimators, it needs to subtract the group average from every observation, so the individual effect will be eliminated. For example, $\mathrm{URIG}^*_{it} = \mathrm{URIG}_{it} - (1/T)\sum_{t=1}^{T} \mathrm{URIG}_{it}$, the model is changed as:

$$\mathrm{URIG}^*_{it} = \alpha x^*_{it} + \beta_1 \mathrm{FIR}^*_{it} I(q_{it} \le \gamma) + \beta_2 \mathrm{FIR}^*_{it} I(q_{it} > \gamma) + \mu_i + \varepsilon^*_{it}. \quad (29.2)$$

Stacked all the observations, Eq. (29.2) can be changed into matrix form as following:

$$\mathrm{URIG}^* = X^*(\gamma)\beta + \varepsilon^*, \quad (29.3)$$

$$\hat{\beta}(\gamma) = (X^*(\gamma)' X^*(\gamma))^{-1} X^*(\gamma)' \mathrm{URIG}^*, \quad (29.4)$$

$$S_1(\gamma) = \hat{e}^*(\gamma)' \hat{e}^*(\gamma), \quad (29.5)$$

$\hat{e}^*(\gamma) = \mathrm{URIG}^* - X^*(\gamma)\hat{\beta}(\gamma)$ is the residual vector. Furthermore, minimum $S_1(\gamma)$ can get the threshold value by using stepwise search method, $\hat{\gamma} = \arg\min S_1(\gamma)$. We can get $\hat{\beta} = \hat{\beta}(\hat{\gamma})$ and $\hat{e}^* = \hat{e}^*(\hat{\gamma})$.

Then we will test statistical significance of threshold effect and authenticity of threshold estimations. For the significance test, null hypothesis is H_0:$\beta_1 = \beta_2$, alternative hypothesis is H_1:$\beta_1 \ne \beta_2$. If null hypothesis is rejected, it means there is threshold effect in the model. Constructing the Lagrange multiplier and the corresponding statistic is:

$$F_1 = \frac{S_0 - S_1(\hat{\gamma})}{\hat{\sigma}^2(\hat{\gamma})}, \tag{29.6}$$

S_0 is the residual sum of squares in null hypothesis, $\hat{\sigma}^2(\hat{\gamma})$ is residual variance in alternative hypothesis. γ is unrecognized in null hypothesis, so the distribution F_1 is non-standard. For authenticity test, null hypothesis is $H_0{:}\hat{\gamma} = \gamma_0$. The corresponding likelihood ratio statistic is:

$$LR_1(\gamma) = \frac{S_1(\gamma) - S_1(\hat{\gamma})}{\hat{\sigma}^2(\hat{\gamma})}. \tag{29.7}$$

The distribution of this statistic is also non-standard, but Hansen [5] provided a formula which could calculate the rejection region. Namely, if $LR_1(\gamma) > -2\log(1 - \sqrt{1-\alpha})$, we can reject the null hypothesis. In this article, we will set FIR as the threshold variable and establish single threshold regression model on the east, middle, west and national area data respectively.

$$\begin{aligned} \text{URIG}^*_{it} &= \beta_1 \text{FIR}^*_{it} I(q_{it} \le \gamma) + \beta_2 \text{FIR}^*_{it} I(q_{it} > \gamma) + \alpha_1 \text{LnRGDP}_{it} \\ &\quad + \alpha_2 \text{URB}_{it} + \alpha_3 \text{ARG}_{it} + \alpha_4 \text{OPEN}_{it} + \alpha_5 \text{EYJ}_{it} + \mu_i + \varepsilon_{it}. \end{aligned}$$

29.4 The Empirical Results and Analysis

29.4.1 Descriptive Statistics

Table 29.1 presents the descriptive statistics of the sample data. The mean of national income gap is 0.125. The east, middle and west areas show an increasing trend. The mean of national financial development is 2.276 and it shows the central collapse phenomenon. The mean of LnRGDP, URB and OPEN shows a decreasing trend in east, middle and west areas, but ARG has a opposite trend. The east mean of is highest followed by west and middle area.

Figures 29.1 and 29.2 are the annual average scatter diagrams. It shows that: income gap has an increasing trend following east, middle, national and west area. Besides, financial development shows an increasing trend every year in general. The national level is close to the west, the east level is highest and the middle is lowest.

29.4.2 The Threshold Effect Test

Tables 29.2–29.5 show F value obtained by the threshold regression which uses FIR as the threshold variable. It shows that in the 5 % significant level, all areas pass the

Table 29.1 Initial decision preference matrix V for decision experts

Group	Variables	URIG	FIR	LnRGDP	URB	ARG	OPEN	EYJ
National area	Mean	0.125	2.276	8.706	0.320	0.078	0.035	0.211
	Standard deviation	0.059	0.782	0.771	0.160	0.033	0.031	0.080
	Maximum	0.289	6.662	10.664	0.893	0.183	0.242	0.557
	Minimum	0.019	1.149	7.111	0.127	0.009	0.001	0.063
East area	Mean	0.082	2.523	9.266	0.427	0.059	0.065	0.228
	Standard deviation	0.037	1.113	0.671	0.195	0.028	0.043	0.073
	Maximum	0.154	6.662	10.664	0.893	0.171	0.242	0.557
	Minimum	0.019	1.149	7.894	0.156	0.014	0.011	0.123
Middle area	Mean	0.110	1.933	8.510	0.293	0.082	0.022	0.245
	Standard deviation	0.033	0.389	0.618	0.105	0.030	0.013	0.090
	Maximum	0.175	3.195	9.900	0.485	0.183	0.074	0.479
	Minimum	0.037	1.247	7.484	0.144	0.012	0.002	0.074
West area	Mean	0.174	2.277	8.324	0.241	0.092	0.015	0.173
	Standard deviation	0.053	0.460	0.643	0.084	0.032	0.012	0.062
	Maximum	0.289	3.417	10.200	0.434	0.180	0.066	0.400
	Minimum	0.045	1.275	7.111	0.127	0.009	0.001	0.063

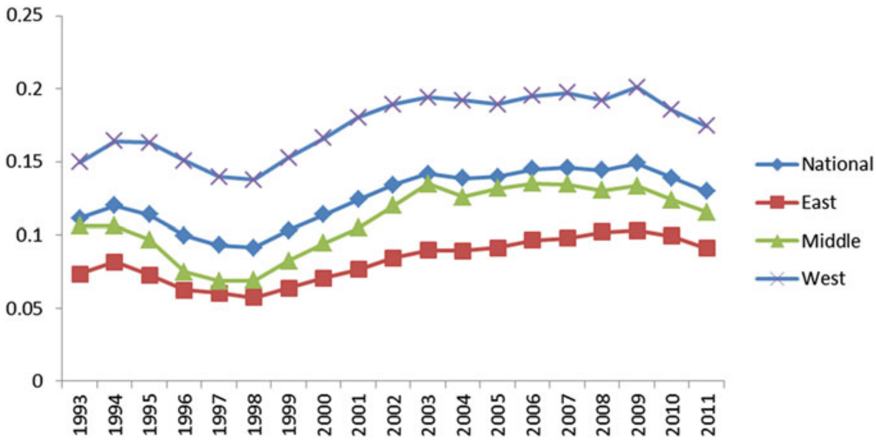

Fig. 29.1 Group conflict coordination framework for emergency decision

single threshold effect test, but the middle area fails in the double threshold test. So the article will choose the single threshold model.

The estimated values and 95 % confidence intervals are shown is Table 29.6 and Figs. 29.3–29.6 are the likelihood ratio curve threshold variable (FIR).

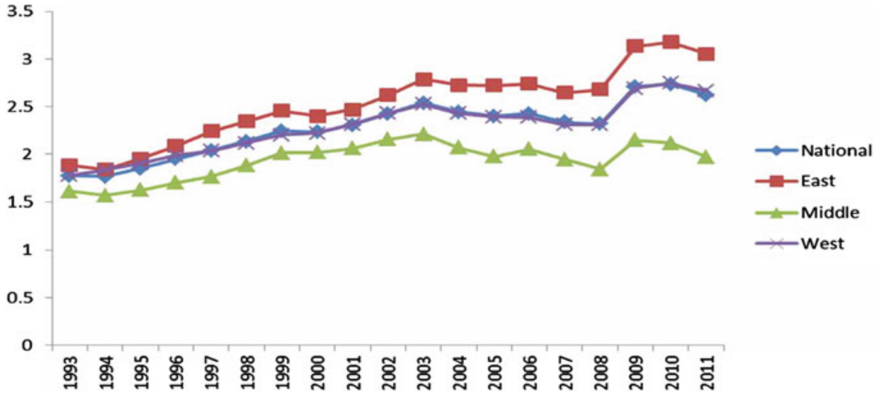

Fig. 29.2 Group conflict coordination framework for emergency decision

Table 29.2 The threshold effect test in east area

	F-statistic	*P*	1 % Reference value	5 % Reference value	10 % Reference value
Single	32.137***	0.003	24.539	13.222	8.856
Double	12.431**	0.033	16.980	8.646	6.996
Treble	7.320*	0.100	14.401	11.977	7.028

Note ***,**,* represent respectively that they have passed the test in the significant level of 1 %, 5 % and 10 %.

Table 29.3 The threshold effect test in middle area

	F-statistic	*P*	1 % Reference value	5 % Reference value	10 % Reference value
Single	8.274**	0.050	14.829	8.384	5.471
Double	3.145	0.190	9.084	6.209	4.846
Treble	1.964	0.190	4.725	3.319	2.326

Table 29.4 The threshold effect test in west area

	F-statistic	*P*	1 % Reference value	5 % Reference value	10 % Reference value
Single	24.295***	0.010	24.385	14.560	10.265
Double	10.461**	0.050	13.250	10.355	7.410
Treble	7.082	0.120	14.666	10.269	7.718

Table 29.5 The threshold effect test in national area

	F-statistic	*P*	1 % Reference value	5 % Reference value	10 % Reference value
Single	52.084***	0.000	17.472	8.996	7.291
Double	8.928**	0.047	17.701	8.898	6.431
Treble	4.575	0.160	12.822	9.790	6.222

Table 29.6 The threshold effect test in national area

	Estimated value	95 % confidence interval
National area	1.896	[1.875, 2.031]
East area	1.646	[1.634, 1.660]
Middle area	1.482	[1.405, 2.478]
West area	2.002	[1.872, 2.024]

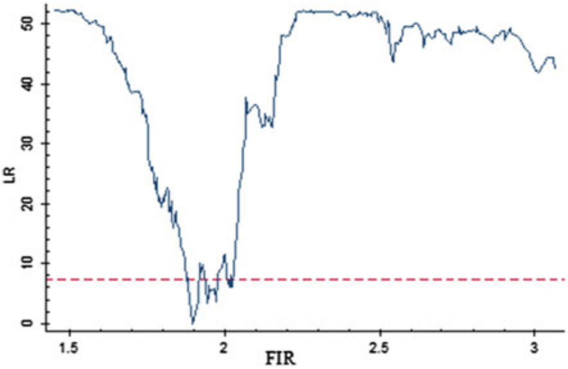

Fig. 29.3 National likelihood ratio curve

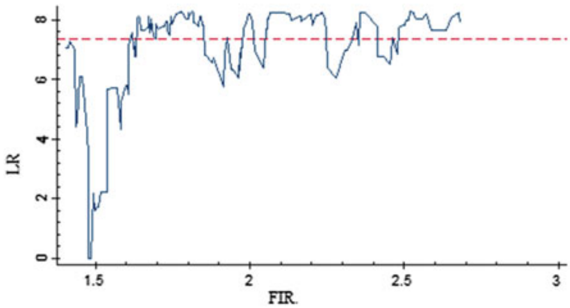

Fig. 29.4 East area likelihood ratio curve

29.4.3 Model Estimation and Analysis

According to the tests above, the article will use single threshold model to estimate the parameters and the results are shown in Table 29.7.

It shows that regional differences exist in the relationship between financial development and urban–rural income gap.

The results of regression show that: (1) Financial development will narrow the urban–rural income gap initially and then widen the gap when reaching a certain level. (2) The threshold values of financial development are highest in the west area,

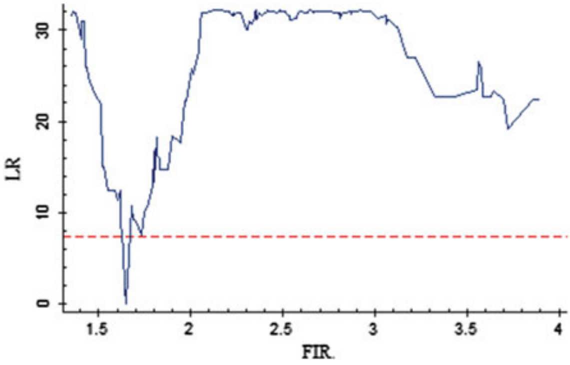

Fig. 29.5 Middle area likelihood ratio curve

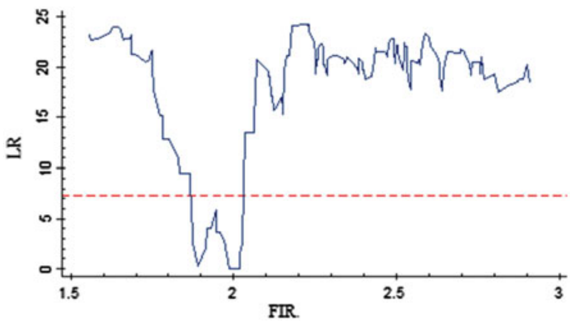

Fig. 29.6 West area likelihood ratio curve

Table 29.7 Estimators of parameters

Variables	Decision schemes			
	East area	Middle area	West area	National area
LnRGDP	0.022*** (5.47)	0.015*** (2.9)	0.028*** (3.17)	0.023*** (7.13)
URB	0.070** (2.25)	0.083 (0.88)	−0.179(−1.52)	0.032 (0.87)
ARG	−0.039(−0.68)	−0.077(−1.23)	−0.190**(−2.62)	−0.146***(−3.50)
OPEN	0.199***(5.75)	0.277* (1.75)	−0.115(−0.56)	0.131*** (2.64)
EYJ	−0.033(−1.54)	−0.177**(−6.19)	−0.213***(−3.92)	−0.117***(−5.66)
$\text{FIR}_{it} I\ (q_{it} \leq \gamma)$	−0.023***(−6.67)	−0.021*(−1.32)	−0.037***(−3.45)	−0.026***(−6.97)
$\text{FIR}_{it} I\ (q_{it} > \gamma)$	0.014***(5.42)	0.010** (3.46)	0.020*** (4.72)	0.013*** (5.84)

followed by east and middle area. (3) The narrowing effect of financial development is greater than the widening effect.

The results of control variables show that: (1) Regional economic growth has consistent results in nation as well as east, middle and west area, which will widen the urban–rural income gap. (2) Urbanization will widen income gap in the east area at 5 % significant level but not statistical significant in other area. (3) Agriculture financial support will narrow the urban–rural income gap but not statistical significant in east and middle area. (4) Opening-door policy will widen the urban–rural income gap. (5) The elimination of urban–rural dual economic structure will significantly narrow urban–rural income gap although the effect in east is weak.

29.5 Conclusion and Recommendation

This paper studies relationship between financial development and urban–rural income gap then analyzes regional differences. Results showed that financial development and urban–rural income gap had a nonlinear relationship. Financial development will narrow the urban–rural income gap initially then widen the gap when reaching a certain level and the effects have significant regional differences. Before crossing the threshold values, with the increase of financial development level, the degree of narrowing the income gap in West region is bigger than that in East and Middle areas.

Based on the conclusions shows above, the policy implications of this paper are: (1) Combining industrial structure with financial development levels of different regions to formulate financial policy, then promote regional economic development and narrow the urban–rural income gap. For example, adopting differentiated regional credit policy and interest rate policy and so on. (2) Smoothly advancing the industrial transfer in the middle and west regions to promote the coordinated development of regional economic interaction. (3) Accelerating to eliminate the dual economic structure in urban and rural areas. The government should vigorously develop the financial resources in rural areas, and increase the supply of rural financial services, and then the problems of scarce financial resources and inefficiency could be solved effectively. All of these will facilitate the narrowing of the urban–rural residents' income gap of all regions. (4) Strengthening the financial support for agriculture in the west area, and continue to promote urbanization, which will help to narrow the urban–rural residents' income gap.

Acknowledgments The research is supported by The key Building Subject of Shanghai Board of Education—"The Operation and Control of Economics System" (J50504).

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Chapter 30
Strategic Analysis of Garden City of Chengdu with SWOT Method Based on Ecological Civilization

Mao Lu, Wenke Wang, Hui Li and Yalan Yang

Abstract This paper analyzes various factors of Garden City of Chengdu with SWOT analysis method. On this basis, the qualitative analysis results are quantified using AHP method. Subsequently, the suitable development path of the Garden City of Chengdu was calculated in this paper with a quantitative SWOT model based on discrete valuation. Then the development path is determined which is WO strategy, or an Adjustment-Fight strategy. According to the WO strategy, Chengdu City should avoid her weaknesses, utilize external opportunities, and strive to achieve the goal of Garden City.

Keywords Ecological civilization · Garden city · SWOT method · AHP

30.1 Introduction

The development of human has experienced three periods: primitive society, agricultural civilization and industrial civilization. However, the industrial civilization which is the most booming one among the three periods has seriously jeopardized the ecological balance of human and natural environment. Nowadays people propose to develop "Ecological Civilization" in order to mitigate the deteriorating natural environment [5]. "Ecological Civilization" includes the harmonious dependence relationship of man and nature, progressive social civilization form and

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_30,

sustainable economic development model. Moreover, it puts the harmony dependence relationship of man and nature, which is the basis for the reproduction of economy and society, to the first place so that it can help the harmonious development of human and nature [6].

The most common example for the deterioration of ecological environment is the deterioration of urban environment. Under the circumstances, the British Howard came up with the idea of "Garden City" to construct an ideal city sharing the advantages of both urban and rural city in 1898. There are three essences of "Garden City". Firstly, the beauty of nature, it means the fusion of nature and city. Secondly, the justice of social, it implies the fair chance for everyone and full employment of society. Lastly, the union of urban area and rural area, means to replace the separation of urban and rural area with the reciprocity of urban and rural area. The purpose of "Garden city" is to realize a coordination of ecological civilization construction in urban and rural area and to establish a benign circle of urban and rural social economy [11].

That the government of Chengdu proposed to construct a "Chinese Modern Garden City" in 2010 was due to the worsening of environment of Chengdu and the increasing negative effect in Chengdu. This proposal is an embodiment of ecological civilization construction in order to ameliorate the environmental problem and has significant theoretical value and practical value. How to develop "Garden city" in Chengdu, however, it is a topic which needs detailed discussion. This paper uses quantified SWOT method to find the right path of Chengdu to develop a "Garden City".

30.2 SWOT Method

SWOT means Strength Weakness Opportunity Threats [1]. It has four factors related with the object of study. They are: S (internal environment strength), W (internal environment weakness), O (external environment opportunity) and T (external environment threats). We match internal and external environmental factors in the form of matrix and analyze the various matching results to get a serious of conclusion as the basis of decision-making on the object of study.

There is an obvious defect in quantitative analysis because early SWOT method is mainly used for the qualitative analysis [2, 14]. The SWOT has the weaknesses in the measurement and evaluation steps [3], which merely pinpoints the number of factors in S, W, O or T groups but does not determine the quantitative effect of each factor on the proposed plan or strategy [4, 7]. A variety of improved quantitative SWOT methods have been proposed by scholars [8, 9, 12]. This paper uses discrete quantitative SWOT method [10] to evaluate the quantized value of matching result in qualitative SWOT analysis because the data involved is discrete. And the method of AHP can help us deal with the analysis of discrete data.

30.3 The General Situation of Chengdu and SWOT Qualitative Analysis

1. The General Situation of Chengdu

The climate in Chengdu is a humid subtropical monsoon climate. The terrain of Chengdutilts from west to east. The highest altitude of mountains in the west of Chengdu is 5,363 m and the lowest altitude of plain in the middle and east of Chengdu is 387 m. The terrain of Chengdu includes plains (40.1 %), mountains (32.3 %) and hills. And the special entertaining culture of Chengdu which has been formed since ancient time is hard for other cities in China to emulate. In the following passage we do SWOT qualitative analysis of Chengdu and the relevant data mainly come from official website.

2. Strengths

The strength of water resources ($S1$):

Chengdu is located in the Minjiang river and Tuojiang river basin of Yangtze River tributary. The annual average water of Chengdu is about 27 billion cubic meters. Chengdu is called "the Nature's Storehouse" because of Dujiangyan Irrigation System which was built thousands years ago. Dujiangyan Irrigation System has been helping people in Chengdu to enjoy a sufficient supply of water during more than two thousand years. Since "the Reform and Opening Policy", Chengdu has experienced a slight pollution of water resources to a serious pollution. But the industrial water pollution in Chengdu has been mitigated since Sichuan became the "Green GDP Accounting Pilot Province" in 2005.

The strength of animal and plant resources ($S2$):

Chengdu is suitable for the living of animals and plants because the soil in Chengdu is sufficient in nutrient and the climate in Chengdu is balanced. By 2011, the city's primeval forest accounted for 9 % of the city total size and the forest coverage rate reached 37.3 %. The size of primeval forest and national nature reserve in Chengdu is the largest among all the provincial capital cities in China so that it contributes a lot to the development of tourism.

The strength of culture ($S3$):

Chengdu has been regarded as "the Nature's Storehouse" for thousands of years. Recently Chengdu won many honorable titles such as "A City Without Industrial Pollution", "A City of Polite" and "The Capital of Delicacy" etc.

The strength of economy ($S4$):

By 2012, the GDP of Chengdu reached a total number of 818.39 billion yuan. The comprehensive competitiveness of Chengdu ranked 16th in "Urban Competitiveness Report of China (2012)" all over the country and ranked 2nd in the western region. The GDP of Chengdu accounted for 34.3 % of the GDP in the whole province and is the most important part of the economy of Sichuan. The terrain of Chengdu is conducive to the development of agriculture, mining enterprises and business planning.

3. Weaknesses

The density of population ($W1$):

By 2012, the resident population of Chengdu was 14.178 million and the population density was 1,144.3 people per square kilometer. The population density of city area is 11,363 people per square kilometer regardless of the floating population. The excessive concentration of population leads to problems like environmental degradation and conflicts with the idea of "Garden city". Los Angeles, the famous "Garden City", its density of garden city is about 3,200 people per square kilometer and the population density in Phoenix is about 1,100 people per square kilometer.

The quality of water ($W2$):

The control of industrial sewage in Chengdu is better than the control of domestic sewage in Chengdu. The direct emission of domestic sewage in the intersections of cities and countries has caused serious pollution in rivers. The quality of surface water in Chengdu was identified as mild contamination in 2012, but V water section accounted for 13.2 % of the total amount of water. The major indicators of water quality are the amount of phosphorus, ammonia nitrogen, biochemical oxygen demand and chemical oxygen demand.

The quality of air ($W3$):

Once there is dust or debris, they are not easy to sinking and floating away because Chengdu is located in the bottom of the Sichuan basin. Considering the quality of Chengdu environmental air the good rate of urban area was 78.1 % which is the 3rd national standard and the good rate of rural area reached the 2nd national standard. Automobile exhaust is the main source of sulfur dioxide and nitrogen dioxide. In addition the foodservice lampblack and seasonal straw burning is also one of the causes of air pollution.

Other pollution ($W4$):

Noise pollution exists in Chengdu. In 2012, the average equivalent sound level of road traffic noise was 69.3 dB in Chengdu's urban area and the quality of sound environment was the secondary level.

The weakness of economy ($W5$):

Although the GDP of Chengdu achieved 818.39 billion yuan, the economic basis of Chengdu is not solid enough to implement the planning and construction of "Garden city" which is such a grand goal of the human race. And moreover, it is difficult to maintain the economic growth not at the cost of environmental degradation.

4. Opportunities

National policies ($O1$):

In the 1990s, the central government of China began to mention ecological civilization. The 15th National Congress put forward to carry out the strategy of sustainable development; then the 16th National Congress put forward the construction of ecological civilization; the 17th National Congress strengthened the ideal of ecological civilization.

The support of government (*O*2):

The government of Sichuan devised the overall planning of ecological civilization in Sichuan in 2004. In 2010, Chengdu officially launched the construction of "Modern Garden City". Government of Chengdu aims to promote the ecological management and protection of the environment. The government spent 1.18 billion yuan on the protection projects of environment from 2009 to 2011 and 2.68 billion yuan on the renovation projects.

The support of citizens (*O*3):

The construction of "Garden City" in Chengdu cannot go on without the support of citizens. As the political and cultural center of Sichuan province, the executive power of policy in Chengdu is strong and the overall quality of citizens is high. As for the construction of "World Modern Garden City" in Chengdu, 2010, the rate of awareness among all the citizens in Chengdu was 83.5 %, and the rate of approval among citizens aware of it was 98 %.

5. Threats

Current Situation (*T*1):

The situation is good at present, but there are still some problems that cannot be ignored. The first thing to consider is how to improve the quality of population and the consciousness of ecological civilization among people. The second thing is to come up with effective methods to control the discharge of pollutant and strategies to improve the ecological environment.

External competition (*T*2):

Hangzhou and Suzhou are both great examples of the development of "Garden City" in China. Chengdu needs to make good use of its advantages to enhance the competitiveness of the city. Good foreign examples such as Los Angeles, Phoenix and Tucson, they are samples for the development of future and they are also basic standards for evaluating a "Garden City". To catch up with these cities, there will be so many challenges waiting for Chengdu in the future.

30.4 The Construction of SWOT Method on the Basis of AHP

1. Calculate the Intensity of the Strategic Factor for the SWOT Model

Refer to the study of Wang and Gan [12] and Wang and Chen [13] and define the intensity of the strategic factor as:

- The intensity of Strength (Weakness) = the estimated intensity of Strength (Weakness) × relative importance.
- The intensity of Opportunity (Threat) = the estimated intensity of Opportunity (Threat) × relative importance.

The estimated intensities for these factors are about actual level. Positive values mean the strengths and opportunities. Negative values mean the weaknesses and threats. The greater the absolute value, the greater the intensity. The relative importance of each factor is the weight coefficient of each factor.

The intensity of each strategic factors can be calculated by AHP. Each strategic factor which obtained by SWOT methods provide the guarantee for the build of AHP matrix. According to the estimated intensity and relative importance of each factors, the intensity of each strategic factor can be calculated and represented as:

$$Z_i = I_i \times P_i \ (i = 1, 2, 3, \cdots, n). \tag{30.1}$$

When using S, W, O, T to replace Z, it can be represented the intensity of strength strategic, Weakness strategic, opportunity strategic and threat strategic factor respectively. I and P denote the estimated intensity and relative importance of each strategic factors respectively.

Add all the Z_i to get the total intensity of different type.

$$Z = Z_1 + Z_2 + Z_3 + \cdots + Z_n. \tag{30.2}$$

When using S, W, O, T to replace Z, it can be represented the total intensity of strength strategic, weakness strategic, opportunity strategic and threat strategic factor respectively.

2. Calculate the Strategic Angle and Coefficient of Strategic Intensity

The paper adopts the discrete valuation method [13] to build strategic SWOT quantitative decision model for the study of urban construction pastoral orientation, using the coordinates of the gravity of SWOT Strategic quadrilateral as an initial basis for strategic positioning and using its polar coordinates as the final basis approach for the strategic positioning.

Use the four types of total intensities as semiaxises to form a four half-dimensional coordinate system. Find S, W, O, T in the coordinate system and get a SWOT strategic quadrangle. The coordinate of the barycenter is $Q(X, Y)$:

$$Q(X, Y) = \left(\sum X_i/4, \sum Y_i/4\right). \tag{30.3}$$

About the Strategic angle θ ($0 \leq \theta \leq 2\pi$):$\tan\theta = Y/X$, so $\theta = \arctan(Y/X)$.

For a same strategy types, we need to determine the strategic intensity:

$$U = \mathrm{O} * \mathrm{S}, \ V = \mathrm{W} * \mathrm{T}. \tag{30.4}$$

U is positive strategic intensity, V is negative strategic intensity. U and V are both needed for us to decide which intensity is suitable. So we have coefficient for strategic intensity: $P = U/(U + V)$. When $P > 0.5$, we usually take radical strategy; When $P < 0.5$, we usually take conservative strategy.

3. The Determination of Strategy

We use θ to determine the type of strategies and P to judge the intensity of the strategies. Make strategic types and strategic intensity diagram.

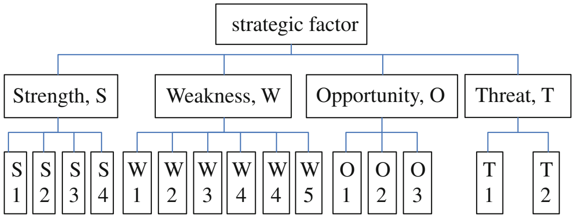

Fig. 30.1 SWOT analysis matrix

Table 30.1 The tables of intensities

	Factors for strength	Factors for weakness	Factors for opportunity	Factors for threat
Intensity	S1 S2 S3 S4	W1 W2 W3 W4 W5	O1 O2 O3	T1 T2
I	3 3 2 2	−3 −3 −2 −1 −2	3 3 1	−2 −1

30.5 Construct AHP Judgment Matrix and Analysis Model

Establish SWOT analysis matrix about the construction of "Garden City" in Chengdu as Fig. 30.1.

According to every strategic factor, evaluate the mark of every intensity and get a judgment matrix. Calculate the relative importance at last and decide the type of strategies. There are nine intensities: 0, ±1, ±2, ±3, ±4. Positive value means strengths and opportunities. Negative values mean Weaknesses and threats. The greater the absolute value, the greater the intensity. We get the table of intensity as Table 30.1.

Apply Field Method to Table 30.2 and communicate with experts to get the judgment matrix as Table 30.3.

Use

$$W_i^0 = W_i / \sum_{i=1}^{n} W_i \text{ and } \lambda_{\max} = \sum_{i=1}^{n} \lambda_{mi}/n,\ w_i = \sqrt[n]{\prod_{j=1}^{n} a_{ij}},\ \lambda_{mi} = \sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} W_j^o / W_i^0$$

to get the weight of every factor and the eigenvalue of every factor respectively: $W_1^0 = 0.036$, $W_2^0 = 0.491$, $W_3^0 = 0.125$, $W_4^0 = 0.078$, $\lambda_{m1} = 4.047$, $\lambda_{m2} = 4.059$, $\lambda_{m3} = 4.046$, $\lambda_{m4} = 4.041$, $\lambda_{\max} = 4.048$.

$C.I$ is the idex for consistency check $C.I = (\lambda_{\max} - n)/(n-1)$, so $C.I = 0.016 < 0.1$.

We know that n is 4 from Table 30.4, so $R.I = 0.89$. $C.R = C.I/R.I$, so $C.R = 0.018 < 0.1$. So the judgment matrix goes through the consistency check.

Then we calculate the judgment matrix for S, W, O, T. The result is in Table 30.5.

According to Eqs. (30.1) and (30.2), we can get the total intensity of strengths (S), the total intensity of weakness (W), the total intensity of opportunity (O) and the total intensity of threats (T): $S = 0.703$, $W = -1.207$, $O = 0.337$, $T = -0.13$.

Table 30.2 The definition of judgment matrix

Scale	Meaning
1	The same importance
3	The former is slightly more important
5	The former is obviously more important
7	The former is highly more important
9	The former is extremly more important
2,4,6,8	The median
Reciprocal	The scale meaning the latter is more important than the former

Table 30.3 The table for judgment matrix

SWOT	S	W	O	T	O	O1	O2	O3		T	T1	T2
S	1	1/2	3	4	O1	1	1/2	3		T1	1	2
W	2	1	4	5	O2	2	1	5		T2	1/2	1
O	1/3	1/4	1	2	O3	1/3	1/5	1				
T	1/4	1/5	1/2	1								
S	S1	S2	S3	S4	W	W1	W2	W3	W4	W5		
S1	1	1/2	1/5	1/3	W1	1	4	2	7	2		
S2	2	1	1/3	2	W2	1/4	1	1/2	3	1/3		
S3	5	3	1	4	W3	1/2	2	1	4	1/2		
S4	3	1/2	1/4	1	W4	1/7	1/3	1/4	1	1/5		
					W5	1/2	3	2	5	1		

Table 30.4 Indexs for the average random consistency

n	1	2	3	4	5	6	7	8	9	10
$R.I$	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

Table 30.5 Indices for the average random consistency

SWOT	S				W					O			T	
Priority	0.306				0.491					0.125			0.078	
SWOT	S1	S2	S3	S4	W1	W2	W3	W4	W5	O1	O2	O3	T1	T2
Divisional priority	0.084	0.213	0.549	0.154	0.402	0.103	0.18	0.047	0.268	0.326	0.524	0.15	0.667	0.333
Overall priority	0.026	0.065	0.168	.047	0.197	0.051	0.088	0.023	0.132	0.041	0.065	0.019	0.052	0.026

According to Eq. (30.3): $Q(X, Y) = (-0.101, 0.051)$, $\theta = \arctan(Y/X) = \arctan(0.051/0.101) = 26.79^\circ$.

Because point P is in the second quadrant, the angle of P and S is 153.210°.

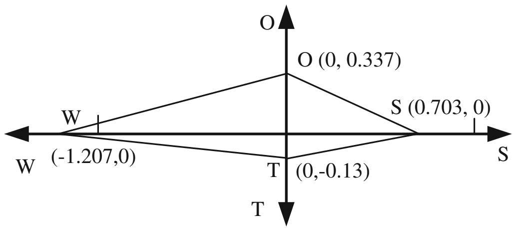

Fig. 30.2 Strategic quadrangle

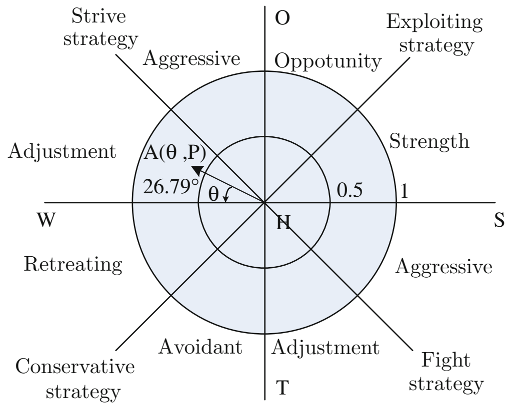

Fig. 30.3 Strategy type and strategic intensity

According to Eq. (30.4): $U = O \times S = 0.337 \times 0.703 = 0.237$, $V = T \times W = 0.13 \times 1.207 = 0.157$, $P = U/(U + V) = 0.602$. We get Figs. 30.2 and 30.3.

The strategy for constructing "Garden City" in Chengdu lie in the $(3/4\pi, \pi)$ area of the second quadrant and $P > 0.5$.

30.6 The Strategy to Construct a "Garden City" for Chengdu

WO Strategy–make use of external opportunities and overcome the internal weaknesses.

With the support from the state, local government and citizens, make full use of the national major policy, strengthen the protection of ecological environment with the help of local finance, and realize the grand target of the development of "Modern Garden City" in Chengdu.

As for the dilemma of rising population density in Chengdu, the government should accelerate the construction of various satellite cities and transfer population from central urban area. At the same time the government should make greater efforts to improve and optimize the quality of citizens so that to make a progress in social civilization.

The protection measures for water environment: Ask for financial support from the government of Sichuan province and vigorously promote the water network repair. Speed up the improvement project of river condition. Establish a complete and scientific sewage treatment system.

The protection measures for air environment: Focus on the solution for pollution of air suspended matter. Increase the punishment of unorganized emissions and advocate the use of clean energy. Increase the investment in public transport which causes less pollution. Furthermore, it can help improve the city noise pollution.

Without the development of economy, there would be no possibility for Chengdu to achieve the goal of "Garden City". Accelerate the economy and improve the environment at the same time through the transformation of the mode of economic growth. Resolutely put an end to any mode of economic growth that is at the expense of the environment deterioration. Close the industrial companies or projects which damage the environmental seriously. Encourage citizens to report pollution they find in their life and respond to their advice immediately.

It is a challenging task for Chengdu to construct the "World Modern Garden City", but I faithfully believe that we will success in the future.

Acknowledgments The research is funded by "Strategic Analysis of Garden City of Chengdu with SWOT Method and Fuzzy AHP Method" (14yb18); "The Department of Education Key Project of Sichuan Province" (13SA0136, 13SA0139); "Innovative Research Team Project of Sichuan Normal University"; "Sichuan Province, Philosophy and Social Science Research Base" (SCKCZY2012-YB005) and "The Department of Education Project of Sichuan Province" (14SB-0022).

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Chapter 31
DYNAMOD—An Agent Based Modeling Framework: Applications to Online Social Networks

Aneesh Zutshi, Antonio Grilo and Ricardo Jardim-Gonçalves

Abstract This paper presents an Agent Based Modeling Framework that seeks to provide a generic model that can be used to simulate any internet based business. The model captures the unique characteristics that define how online users interact, share information, and take product adoption decisions. This model can be used to simulate business performance, make business forecasts, and test business strategies. To demonstrate the applicability of the model, we choose two social networks with opposing scales: Facebook and a startup educational social network—weduc.pt.

Keywords Digital business models · Agent based modeling · Business forecasting · Business simulation

31.1 Introduction

Digital Businesses are the most dynamic of industry segments, and have expanded dramatically over the last decade. Digital businesses encompass the entire gamut of ventures, from online sale of products and services to social collaboration platforms, and have become a vital engine for the new economy. According to a recent McKinsey Report, the Internet economy contributed to 21 % of the overall GDP growth in the past 5 years in mature economies and now accounts for 3.4 % of the GDP [19]. However, understanding this new economy has been a challenge for companies that were tuned to the traditional ways of doing business and were armed with traditional

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_31,

product development and marketing philosophies. Most companies that rushed into the dot-com bubble in the early part of the last decade perished [15]. However, we also saw the emergence of new business giants such as Google and Amazon, who did the right things at the right time to emerge as winners.

There has been limited academic effort trying to understand what makes a digital business a success or a failure. Business Model (BM) has been an active area of research over the last decade, and provides us with a structured approach to represent and comprehend the value delivering mechanism of a business. Walter and Back [28] define BM in the following way: “A business model describes ways of creating value for customers and the way business turns market opportunities into profit through sets of actors, activities and collaborations.” A Business Model is a set of coordinated strategies that ultimately aim to increase the short-term and long-term profitability of an enterprise.

In this paper, we first make a review of the characteristics that make a Digital Business different from traditional businesses. Through a Business Model approach we develop a generic framework that can be used to represent a Digital Business. This framework, a Dynamic Agent Based Modeling Framework (DYNAMOD), further incorporates Agent Based Modeling techniques to model real life business scenarios. DYNAMOD provides a framework to assist business managers develop and test their models in a variety of market scenarios. DYNAMOD will enable the simulation of current market conditions, and enable the visualization of market adoption and growth of a particular business offering, thus enabling the development of a sound Business Model with a much greater chance of success. Finally, we demonstrate some of the capabilities of this model through its application to two social networking sites-Facebook and a startup educational social network—weduc.pt.

31.2 Digital Business Characteristics

Digital businesses refer to the provisioning of products or services through the Internet. They have been the most dynamic entrepreneurial area, requiring agile and innovative business models [8]. Digital businesses have flourished and failed at a scale and pace never seen before by any other traditional business sector [26]. Despite numerous failures, the phenomenal success of new ventures like Google and Facebook have shown that disruptive business models have the potential to exponentially gain market share and expand virally. Here we discuss some of the key characteristics that form the defining features of digital businesses.

31.2.1 Free and Freemium Models Due to Low Cost per User

Digital businesses have a unique feature. While costs of infrastructure and servicing of clients increases over time for traditional businesses, thesecosts have been falling rapidly in the case of digital businesses. The key infrastructure costs—Storage, Processing and Bandwidth, have continued to follow Moore's Law and have steadily plummeted [2]. As companies have embraced economies of scale, the servicing cost per client have been tending to zero [27]. This has led to experimentation with new business models that reflect these low incremental per-user costs. Very low per-user costs have led to the growth of Free and Freemium business models, where the end user receives tangible products or services without a cost. While Free services are mostly supported by advertising, in case of Freemium, a small percentage of people pay for premium services, or generate revenue through indirect sources [27].

31.2.2 Viral Marketing

Viral Marketing refers to the fast and infectious spread of a product adoption across the market. It involves strategies for rapid uptake of electronic peer to peer referrals [5]. It also involves an effective utilization of word of mouth or established networks of clients, through an excellent value proposition that is low cost or free. In electronic business, automated viral marketing strategies are sometimes used to induce viral marketing with little intervention from the users, or sometimes even without the knowledge of users. A commonly cited example is Hotmail, which became very popular due to automatically adding its web-link at the end of each email sent by a Hotmail user [21].

However excessive viral marketing might create a perception of the product as spam and lead to negative opinions about the product in the minds of potential adopters [18]. Hence, although it is an effective tool, viral marketing must be carefully exploited.

31.2.3 Intense Competition

Another feature of digital business is intense competition. Since entry barriers to markets tend to be low and national boundaries are not significant hurdles, the entry of new competitors takes place at a phenomenal speed [20]. In traditional businesses, a large number of competitors would have meant a highly fragmented market share. A unique feature of digital business is that often a dominant player assumes an extremely large proportion of the market share. This is because of the low cost structure (often zero or near zero) of the digital business, where pricing cannot be used as a differentiating parameter. The network effects associated with well connected users mean that a well designed product, usually the first mover, would virally expand due to positive customer feedback [10]. Marginal deficiencies in the product or services offered can lead to customer dissatisfactions that can propagate through the network of the potential user base, with a considerable effect on future product adoption. This is especially true since forums and product reviews are easily accessible to customers today.

31.2.4 Product and Marketing Integration

Digital markets often do not provide room for drawing board development of business strategies that can be slowly tested in the market and tweaked as time goes on. For effective marketing in the digital world, marketing strategies should not be separate from product, but rather marketing should be built into the product itself [16]. Market opportunities must be quickly exploited, before a competitor catches up. This integrated approach to the digital business strategy, which incorporates product development, marketing and pricing forms the underlying principle of a digital business model.

31.2.5 Network Effects

Network effects exist when consumers derive utility from a product based on the number of other users [14]. These effects are especially relevant for several online businesses, especially since various online products and services exhibit some form of network effects, such as social networking sites and online marketplaces. Goldenberg et al. [14] also predicts a chilling effect of network externalities. They propose that a product with a network externality has a slower initial adoption compared to a product that does not have any network externalities. The higher growth rate due to the network effects occurs only after the product has crossed a certain adoption critical threshold.

31.2.6 Pricing of Information Goods/Services

Pricing of digital products often involves splitting the product into different sub-categories and re-bundling them. The unit of charge for digital products must change. Smaller units of charge, focusing on pay per use or per month subscription charges have met with success in the digital world [8].

31.3 Agent Based Modeling (ABM) Approaches to Simulate Business Environments

Traditional management guidelines are ill-equipped to help understand the digital business models and predict success and failure. New tools and techniques are necessary to help model the complex nature of online products and services. Hence we have developed a generic framework for a customizable simulation environment that can capture the dynamics of an online market, and provide Business Managers with tools to simulate and forecast, thus acting as a tool to perfect their Business Model.

Online markets can be represented as a network of interconnected online users which share positive and negative feedbacks and respond to different online products and services. If the behavior of individual agents can be sufficiently well modeled, then a natural candidate for representation is Multi-Agent Based Modeling Techniques. ABM is build on proven, very successful techniques such as discrete event simulation and object oriented programming [22]. Discrete-event simulation provides a mechanism for coordinating the interactions of individual components or "agents" within a simulation. Object-oriented programming provides well-tested frameworks for organizing agents based on their behaviours. Simulation enables converting detailed process experience into knowledge about complete systems. ABM enables agents who represent actors, or objects, or processes in a system to behave based on the rules of interaction with the modelled system as defined based on detailed process experience. Advances in computer technology and modelling techniques make simulation of millions of such agents possible, which can be analysed to make analytical conclusions.

Tesfatsion introduced Agent-Based Computational Economics as the computational study of dynamic economic systems modeled as virtual worlds of interacting agents. Aliprantis et al. [1] have applied ACE to retail and wholesale energy tradings in the Power Markets. In this paper we extend the concept of Agent-Based Computational Economics, to develop DYNAMOD-An Agent Based Modeling Framework for online Digital Business Models.

31.4 Theoretical Basis for the DYNAMOD Model

The development of the DYNAMOD model, is based upon other previous research works in diverse areas. Some key concepts that have been applied in the model are discussed below.

31.4.1 Diffusion of Innovations

Diffusion of Innovations has been an active research area and reflects adoption decisions made by individual consumers. These decisions are made in a complex, adaptive system and result from the interactions among an individual's personal characteristics, perceived characteristics of the innovation, and social influence [23]. There are two major approaches to modeling diffusion: econometric and explanatory. The concept of Econometric Modeling was first introduced by Bass [3]. Econometric approaches forecast market uptake by modeling the timing of first-purchases of the innovation by consumers and are more applicable when market growth rate and market size are of primary interest. Explanatory approaches, as first proposed by Gatignon [11] establish that the diffusion of a product in a defined market is equivalent to the aggregation of individual consumer adoption decisions. The adoption decisions are dependent on: Personal characteristics, perceived product characteristics, and social influence.

In earlier works, diffusion of innovation has been approached with mathematical modeling [12–14]. However as computational powers increased, relatively recent attempts have been made to complement these classic approaches with Agent Based Modeling tools [6, 7, 24]. We have used these works as the basis for developing the DYNAMOD model with the application of specific characteristics to differentiate online businesses.

31.4.2 Word of Mouth

Literature has assumed word of mouth (WOM) to be the influence of neighbors over an individual [9]. This is a relevant assumption for offline word of mouth since such communication is mostly limited by geographical location.

Word of mouth communication is more effective when the transmitter and recipient of information share a relationship based on homophily (tendency to associate with similar persons), trust and credibility. Brown et al. [4] conducted research on online word of mouth and report that online homophily is almost entirely independent of interpersonal factors, such as an evaluation of individual age and socio-economic class, traditionally associated with homophily. The idea of individual-to-individual social ties is less important in an online environment than in an offline one. Individuals tend to use websites as proxies for individuals. Thus, tie strength was developed between an information seeker and an information source as offline theory suggests, but the information "source" is a Web site, not an individual.

31.4.3 Network Structure

Cellular Automata, is a form of lattice network and has been used by numerous authors to mathematically model word of mouth. They represent users as cells in a cellular grid like network, with each a cell getting influenced by static neighbouring cells surrounding them. Goldenberg et al. [12] used cellular automata and introduce the concept of strong ties and weak ties while discussing word of mouth. However the static nature of the network makes it unsuitable to represent the dynamic nature of online user networks. Another form of a network is a random network where the cell distance is randomly distributed. Another common network methodology is the small-world network which starts with a random network randomly rewiring some of the edges [25].

In the case of DYNAMOD, we shall be using a dynamic random network where user agents start being randomly distributed over a flat world, and get influenced by agents in a fixed radius. However the agents themselves slowly make random walks,

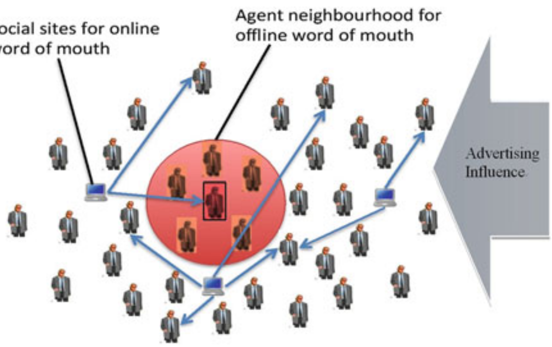

Fig. 31.1 Conceptual representation of the DYNAMOD framework

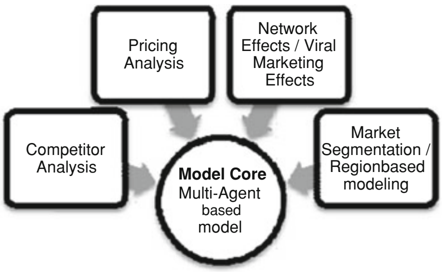

Fig. 31.2 DYNAMOD component architecture

and thus the agents within their sphere of influence keep changing. This represents an online world where users constantly meet the opinion of new users through online posts and forums.

31.5 The DYNAMOD Framework

The DYNAMOD Framework has been developed based on the academic literature collected. Its purpose is to provide researchers and companies engaged in online businesses with a tool for quickly developing Computational Modeling Systems that can represent their Business Models and their Business Environment, in order to perform advanced simulations for predicting business growth dynamics. DYNAMOD is based on Agent Based Modeling, which enables dynamic representation of the online marketplace. Every online user that could be a potential customer for a product or service is represented as an Agent in DYNAMOD (see Fig. 31.1). These agents interact with each other and share information about new products and services. At the same time, they are influenced by Advertising and Social sites. The model captures these influences, and simulates their impacts in order to predict future scenarios.

The model is customizable and extendible to implement a diverse set of Business Model components, and to make a variety of simulations. Figure 31.2 shows a conceptual relationship of the various components the DYNAMOD Framework. The model core consists of many interacting agents that represent a market. The model includes standard variables and logics for implementing influence and satisfaction scores for each agent. This core component handles the simulation and interaction, and defines what constants are needed to initialize the key features of the model.

Other features are added to the model in the form of modules, as and when necessary, for different case scenarios. In the current scope of the model, four additional modules have been envisaged, namely Competitor Analysis, Pricing Analysis, Network Effects/Viral Marketing Effects, and Market Segmentation/Region Based Modeling, but additional components can always be added for modeling other scenarios.

Competitor Analysis involves introduction of competitors who can have competing influences on consumers, and then monitoring the switching behavior of consumers. *Pricing Analysis* involves introduction of various charging units, and their impacts on consumer adoption. It also involves the introduction of Freemium Business Models into the model, and simulates the adoption of Free and Paid components of the Businesses. This module is not needed in case of Free Business Models. Businesses that have an inherent *Network Effect* or are based on *Viral Marketing* need to add additional logics that change the rate of product adoption. The *Market Based Segmentation* or *Region Based Modeling* changes the dispersion of agents in the model space, to represent different clusters of agents. This can represent different classes of customers with varying purchasing powers, or can represent customers on different continents.

31.6 Case Studies of 2 Contrasting Social Networks

One of the most powerful forms of digital business is a Social Network. It harnesses the power of the web to easily connect communities and promote social interactions. The largest social network site in the world is Facebook in terms of number of active users. However several niche social networking based digital businesses have been launched ranging from product reviews to forums and blogs.

We have selected two case studies: Facebook and an online Educational startup-WeDuc. While both these cases are examples of Online Social Networks they are two contrasting examples. While Facebook is a highly mature company and due to the positive network effect due to its large number of users, would find it difficult to be replaced by competitors. In contrast WeDuc is a startup and is still trying to establish its Business Model.

31.6.1 Facebook Forecast Using DYNAMOD Model

The Model was initialized based on active monthly users historical data from June 2009 untill June 2011, and based on questionnaires collected from 112 respondents out of which 102 were Facebook users. The questionaires gauged their satisfaction

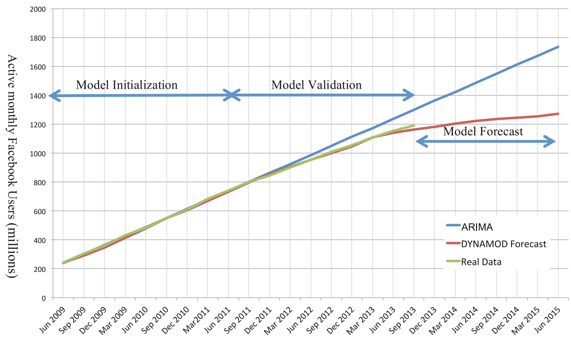

Fig. 31.3 DYNAMOD forecasts for Facebook

levels and measures the degree of word of mouth and were used to initialize the model. After initialization, the model was used for making forecasts of future user adoption until June 2015. The actual data after June 2011 are used only to verify the predictions of the model. To test the accuracy of forecast by the DYNAMOD model, we also used another forecasting tool-ARIMA (Fig. 31.3).

- Total number of customers at any time C_t according to the Dynamod model $= A_i^{\text{client}=1}$.
- Number of customers according to data at any month $t = C^A t$.
- Number of customers at any month t according to the ARIMA Forecast = R_t.

The Root Mean Square Error for the initialization data was:

$$\frac{\sqrt{\sum_{\text{Jun 09}}^{\text{Jun 11}} (C_t - C^A t)^2}}{\text{Count} - \text{Records (Jan 09–Jul 11)}} = 3.18.$$

The actual growth of Facebook active users slows down over the validation period. Hence the regression line moves away from the actual growth line. However the DYNAMOD model is able to predict the slowdown and closely follows the actual growth line.

For the Validation Period between Sep 2011 and Sep 2013, RMS Error during Validation phase for DYNAMOD prediction was:

$$\frac{\sqrt{\sum_{\text{Sep 11}}^{\text{Sep 13}} (C_t - C^A t)^2}}{\text{Count} - \text{Records (Sep 11–Sep 13)}} = 3.91.$$

For the same Validation phase, the ARIMA Error was:

$$\frac{\sqrt{\sum_{\text{Sep 11}}^{\text{Sep 13}} (Rt - C^A t)^2}}{\text{Count} - \text{Records (Sep 11–Sep 13)}} = 19.08.$$

This validates that the DYNAMOD model forecast is closer to real data than the Regression Model. This demonstrates that DYNAMOD can be leveraged for business growth simulations, in this case, a very mature business which has already reached a majority of global users.

While the main aim of the Model is not to be used as a pure forecasting tool, a good forecast ensures that the model is efficiently configured and ready for making further analysis.

31.6.2 Case Study of an Educational Social Network Startup-WeDuc

Weduc.pt is a Portuguese startup educational social network with the aim of providing a secure environment for Parents, Teachers and Students especially aimed at Primary and Secondary Schools. The site allows for a user-friendly interface where parents can keep track of the progress of their children at schools. Teachers can communicate individually with students and their parents, post homework, evaluations and also conduct online tests. Finally the students can interact with their peers, have discussions on topics, and experience social networking under the supervision of Teachers and Parents to make sure that they are not exposed to any unsuitable content. Despite being a social network, it does not exhibit a network effect because in effect it consists of individual islands of social networks for each school. The key decision for adoption is taken by the school administrators.

The website started conducting its first trials in September 2010 and when this research was conducted in July 2013, had registered 300,000 users across 2,000 schools. However the existing Freemium business model was only established in 2013.

31.6.2.1 Business Model

Currently weduc.pt is using a freemium business model where basic subscription is offered free to schools and while paid subscriptions cost 5 Euro per child per month. The paid option includes access to high resolution images, videos, file uploads, customised school theme, telephonic support and training of teachers. The school management takes the decision to either go for the free subscription or the paid one. Consequently, most of the schools opting for the paid price plan are the private schools. As on the date of the study, out of the 2,000 schools registered in Portugal, only 40 schools had opted for the paid tariff plan.

Ninety nine percent of the total revenues are generated through subscriptions while only 1 % is through online advertisements. While most subscriptions are the result of direct marketing to school administrators, other sources of marketing that have been used include online advertisements, radio ads and advertising on Facebook. 20 % of

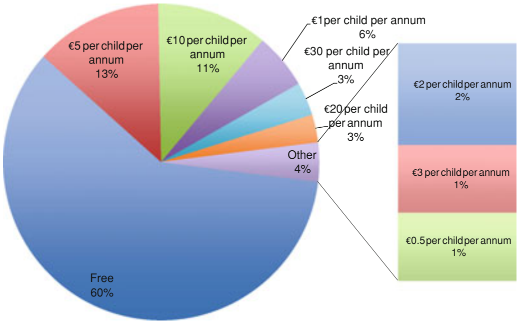

Fig. 31.4 Willingness to pay by parents of children in schools with free tariff plan

overall budget have been spent on Marketing and 70 % of the budget has been spent on Product Development.

31.6.2.2 Implementation of DYNAMOD Model

Since weduc.pt did not benefit from such a vast historically recorded user data after the implementation of the existing freemium pricing model, it was difficult to make accurate growth forecasts using DYNAMOD model. Rather the focus of DYNAMOD in such early stage startups is to test the impact of changes in the current Business Model.

Model Objective: Currently the school management takes the decision between choosing a free subscription and a paid subscription and pays for all the students in the school. This has led to only 40 out of 2,000 schools taking the paid service. The objective of this simulation was to see the impact if instead of the School Management making the decision, individual parents were able to choose between paid and free subscription for their kids.

Methodology: To develop the DYNAMOD model the schools were selected as the main agents within the Agent Based Model. Since the aim of this model was not to simulate the adoption by new schools but rather the analysis of shift in the business model to allowing parents of free schools to upgrade to a paid version. So a macro model was used where schools were the agents with a range of students from 50 to 500 per school. A subsequent mini model was created to represent a typical school with 300 students to evaluate their parents? willingness to pay. The initialization of this model was based on a survey conducted from July 2013 to November 2013 with 288 respondents.

Results: Fig. 31.4 shows the response of the parents of children in schools choosing the free version when asked about their willingness to pay for a paid version. While 60 % of the respondents chose to not pay, 11 and 13 % of the respondents chose to pay annually €10 and €5 respectively. 30 % of the respondents chose to pay at least €5. Hence there was a compelling case for monetization of revenues from a sizable percentage of the new users. However the only drawback was any negative impact from different children in the same school having different features. This could reduce the satisfaction level of students whose parents don't subscribe to the paid version thus impacting the overall satisfaction. According to the simulation result, offering this option could enable weduc to increase their revenue share by 23 %.

31.7 Conclusion

The DYNAMOD model demonstrates a systematic approach to representing the key characteristics of digital businesses and developing an Agent Based Model that can act as a forecasting and key decision support tool to study the impact of changes in the Business Model. It is a tool that can be used for startups as well as mature entreprises. We are in the process of developing further application scenarios and case studies to further validate the approach and the results.

Acknowledgments The authors also would like to thank Fundação da Ciência e Tecnologia for supporting the research center UNIDEMI through the grant PEst-OE/EME/UI0667/2011. Also, the authors are grateful to ISOFIN and VORTALWAY projects (QREN) for funding Aneesh Zutshi's research work.

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Chapter 32
The Research on Treasury Bond Futures Market Liquidity Measuring Index Based on OSA Algorithm

Jun Hou, Wenke Wang, Mao Lu and Yan Hu

Abstract The index systems which measures the liquidity of treasury bond futures market are built based on the research of the common liquidity measuring index in this paper, using the high frequency data of treasury bonds futures market and the objective system analysis algorithm. The study shows that the liquidity of China's treasury bond futures market can be measured with the inventory, price fluctuations index, relative bid-ask spread, effective spread and Amihud liquidity ratio. Particularly, the inventory, price fluctuations index and relative bid-ask spread should be attached more importance.

Keywords Objective systematic analysis (OSA) · Treasury bond futures · Liquidity

32.1 Introduction

Futures market's liquidity is a guarantee for the implementation of the basic functions of the futures market, and it is an important factor in determining the existence of a futures contract. After 18 years, bond futures formally restarted on September 6, 2013. Compared with other varieties of futures which are listed on the first day, treasury bond futures and open interest are low, and their liquidities are poor. Liquidity is one of important considerations to determine if bond futures can be launched successfully. Therefore, in order to find ways to promote liquidity, it is necessary to research the liquidity of treasury bond futures market since it has been listed.

Then, how to measure the liquidity, which acts as an important index of futures market' efficiency and function, has always been concerned by the domestic and foreign scholars. Cox [5] firstly use the index of inventory to measure the liquidity of the futures market. Telser [16] built the cost and profit model of futures market using

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_32,

the volume of business and inventory. Schwartz [15] classified liquidity into the depth, width and resiliency of market. Harris [9] provided the market width, market depth, market resiliency and market immediacy as the widely accepted indexes to measure the market liquidity. The literature [1, 2, 4, 6–8, 10, 11, 14, 17, 18] studied the futures market liquidity by the measuring indexes such as the market depth, bid-ask spread, trading volume and liquidity ratio etc. However, various liquidity measuring indexes and methods which the researches have used just reflect some partial characteristics of the liquidity from the specific viewpoint. When faced with a specific marker, how to select a proper measuring index is yet an answered question. Baker [3] pointed out that different liquidity measuring indexes may lead to conflicting results, when market liquidity is assessed. Hence, further studies are needed to determine which index should be selected to measure liquid with the treasury bond futures market of China. Hence, the essay, following the method of literature [13], chooses the commonly used liquidity indexes and utilizes the high frequency data of futures trading to study the treasury bonds futures trading with objective system analysis algorithm.

32.2 Objective System Analysis

Objective system analysis (OSA) is developed based on Group Method of Data Handling (OSA), which is named “rule discovery”. With the method of model equations established by the computer, the most essential characteristic variables and the causal relationship can be founded from several interrelated factors (variables) regarded by experts [12]. The article will use this algorithm to identify the index which can best reflect our treasury bond futures market liquidity from the current liquidity measuring indexes.

The basic principle of OSA eventually determines an equation system (equation group) to describe the economic system which is being studied through a certain kind of evolving mechanism and evaluating criterion. In OSA, the process of selecting equation sets is automatic, and that’s also the reason why the method is called objective system analysis. OSA is derived from self-organization theory, whose evolving mechanism is an increasing complexity of equation sets, while the basic evaluating criterion selected is a minimum aberration one of an external criterion [12].

Based on OSA’s principle, the paper builds a key liquidity metrics selection algorithm:

Step 1. supposing the number of common liquidity metrics is m, the length of data is N. Marking those indexes as x_{ij}, we can get data sample W as follow:

$$\begin{bmatrix} x_{11} & x_{21} & \cdots & x_{m1} \\ x_{12} & x_{22} & \cdots & x_{m2} \\ \vdots & \vdots & \vdots & \vdots \\ x_{1N} & x_{2N} & \cdots & x_{mN} \end{bmatrix}.$$

Step 2. Divide data into groups: $w = A \cup B$, among which the number of sample A & B is equal. We can marked as follows, $p = \{1, 2, \cdots, m\}$, $Q = \{1, 2, \cdots, N\}$.

Step 3. (a) Build the model of $x_i(t)$ (consider one step delay): $x_i(t) = a_0 + a_1 x_i(t-1)$, $i \in P$.

(b) Estimate parameters on A (consider one step delay) to get a model:

$$x_i(t) = a_0^A + a_1^A x_i(t-1).$$

Mark it as $x_i{}^A$.

(c) Estimate parameters on B (consider one step delay) to get a model:

$$x_i(t) = a_0^B + a_1^B x_i(t-1).$$

Mark it as $x_i{}^B$;

(d) Calculate the minimum deviation criterion value:

$$\eta_{bs_i}^2 = \frac{1}{N}\sum_{k=1}^{N}\left(\frac{x_i^A(k) - x_i^B(k)}{x_i(k)}\right)^2, \quad i \in P.$$

(e) Based on minimum aberration criterion value η_{bs}, select F_1 better models (Namely, there are F_1 smaller values of the rule of minimum deviation) Mark the minimum value of the minimum deviation criterion as η_1 in F_1 optimal models.

Step 4. **(a)** Build the model of variable $x_i(t), x_j(t), i, j \in P$ respectively(consider one step delay), using minimum aberration criterion

$$\begin{cases} x_i(t) = a_0 + a_1 x_i(t-1) + a_2 x_j(t) + a_3 x_j(t-1) \\ x_j(t) = b_0 + b_1 x_i(t) + b_2 x_i(t-1) + b_3 x_j(t-1) \end{cases} \quad i, j \in P, \ t \in Q. \tag{32.1}$$

(b) Figure out η_{bs_i} and η_{bs_j} of Eq. (32.1), and get minimum aberration criterion value of the equation set is: $\eta_{bs} = \frac{1}{2}(\eta_{bs_i} + \eta_{bs_j})$.

(c) Select better models and the number is F_2, based on the value of η_{bs}. Mark the smallest of these models' minimum aberration criterion value as η_2.

Step 5. **(a)** Build the model of variable $x_i(t)x_j(t), x_k(t), i, j, k \in P$, respectively (consider one step delay), using minimum aberration criterion:

$$\begin{cases} x_i(t) = a_0 + a_1 x_i(t-1) + a_2 x_j(t) + a_3 x_j(t-1) + a_4 x_k(t) + a_5 x_k(t-1) \\ x_j(t) = b_0 + b_1 x_i(t) + b_2 x_i(t-1) + b_3 x_j(t-1) + b_4 x_k(t) + b_5 x_k(t-1) \\ x_k(t) = c_0 + c_1 x_i(t) + c_2 x_i(t-1) + c_3 x_j(t) + c_4 x_j(t-1) + c_5 x_k(t-1). \end{cases} \tag{32.2}$$

(b) Figure out η_{bs_i} and η_{bs_j} of equation set above, and get minimum aberration criterion value of the equation set is: $\eta_{bs} = \frac{1}{3}(\eta_{bs_i} + \eta_{bs_j} + \eta_{bs_k})$.
(c) Select better models and the number is F_3, based on the value of η_{bs}. Mark the smallest of these models' minimum aberration criterion value as η_3.

Repeat the above-mentioned process until minimum aberration criterion's smallest value $\eta_i, i = 1, 2, 3, \cdots$ is on the rise. Ultimately, the screening process determines variable collections of the complex system and their structures. Those variables corresponded to minimum criterion values' equation sets are "characteristic variables" of the system. And liquidity metrics corresponded to characteristic variables is key liquidity indexes to measure treasury bond futures.

32.3 Data Acquisition and Description

The paper chooses five-year treasury bond futures contract of China Financial Exchange as the object. Because the futures contracts would not exist after the futures contract ends, futures prices which differ from stock prices have a characteristic of discontinuity. Furthermore, the same species of futures contracts will have several different delivery months futures data on the same trading day. To eliminate the influence of these factors, the study adopts the continuous contract constructed by the most traded one of treasury bond futures contracts, each of which has the trading information for one minute, including the purchasing price, selling price, closing price, the highest price, the lowest price, volume and open interest. The starting and ending time of the data selected by the research is September 6, 2013–November 29, 2013. Data comes from Wenhua financial system.

32.4 Selection of Bond Futures Market's Liquidity Metrics

32.4.1 Selection of Initial Variable and Data Preprocessing

On the basis of the research on the previous literature, combined with treasury bond futures market's current situation and the possibility of obtaining data, this study selects initial variables among the four-dimensional liquidity indexes (time-based metrics, price-based metrics, trading volume-based metrics, metrics based on the price impact). In addition, it also adds positions indexes. Although this index does not belong to those four types of liquidity metrics, it reflects the investor's positions, since positions is a special index futures trading which is different from the stock exchange. Through the holdings of the relationship between volume and price change, it can reflect the change of market liquidity. The selections of initial variables are as follows:

1. Trading volume

Measuring the number of transactions in a certain price (or price range), which can directly measure the active degree of market transactions, is one common index to measure the depth of the market. The larger the volume is, the higher the liquidity is.

2. Positions

It is the number of outstanding contracts. Positions can reflect the amount of funds invested into the contracts. The larger the positions is, the higher the liquidity is.

3. Turnover rate

$$\text{Turnover rate} = \frac{\text{Trading volume}}{\text{Position}}. \tag{32.3}$$

The larger the turnover rate is, the shorter the futures contracts holding time is, the higher the liquidity is, and vice versa.

4. Price Fluctuation Index Price fluctuation index is applied to indicate price fluctuation range

$$\text{Price Fluctuation Index} = \frac{\sum \frac{|p_{i\,\max} - p_{i\,\min}|}{p_{i\,\min}} \times Q_i}{\sum Q_i}. \tag{32.4}$$

$P_{i\,\max}$ is the highest price of each minute; $P_{i\,\min}$ is the lowest price of each minute; Q_i is the volume in every minute.

Price fluctuation range is in inverse proportion to liquidity. The larger price fluctuations are, the lower the liquidity is. Otherwise the liquidity will be higher.

5. Relative Bid-ask Spread

$$\text{Relative bid-ask Spread} = \frac{p_a - p_b}{(p_a + p_b)/2}. \tag{32.5}$$

Of which P_a stands for the best selling price, P_b for the best purchasing price.

The greater the relative bid-ask spread is, the higher the instant transaction costs are, the lower the liquidity is, and vice versa. Here, the best purchasing or selling price is replaced by the last purchasing or selling price of a minute.

6. Relative effective spread

$$\text{Relative Effective Spread} = \frac{|2p - (p_a + p_b)|}{p_a + p_b}. \tag{32.6}$$

Of which stands for the transaction price, P_a for the best selling price, P_b for the best purchasing price.

The greater the effective spread is, the higher the actual execution of order cost, the lower the liquidity is, and vice versa.

7. Market depth value

Market depth mainly refers to price depth, which means the amount of orders on best bid-ask quote. The formula is:

$$\text{Depth} = |p_a + p_b| / 2. \quad (32.7)$$

Of which for the amount of orders on lowest ask price, stands for the amount of orders on highest bid price.

The greater the market depth value is, the higher the liquidity is; conversely, the liquidity is lower.

8. Amivest Liquidity Ratio Amivest liquidity ratio is also called conventional liquidity ratio, which was firstly used by Amivest company. It measures the liquidity with the volume (amount of money) needed by 1 % in price variation.

$$L_{con} = \sum_{t=1}^{n} p_{it} V_{it} \Big/ \sum_{i=1}^{n} |\%\Delta p_{it}|, \quad (32.8)$$

where L_{con} stands for liquidity ratio; p_{it} stands for price of future contract i in t phases; $\sum_{i=1}^{n} |\%\Delta p_{it}|$ stands for trading volume of future contract i in t phases; stands for the sum total of absolute price change ratio of future contract i in a certain phase.

The higher Amivest liquidity ratio is, the smaller the effect on price of trading volume is, the higher the liquidity of the future contract is; conversely, the liquidity is lower.

9. Amihud Liquidity Ratio

Amihud liquidity ratio is also called weak liquidity ratio, which refers to the ratio of the absolute return rate and transaction amount of futures contracts in a certain period of time.

$$ILLIQ_t^i = \frac{|\ln p_{i,t} - \ln p_{i,t-1}|}{v_{i,t}}, \quad (32.9)$$

where $ILLIQ_t^i$ stands for weak liquidity ratio of future contract i in phase t; $P_{i,t}$ stands for closing price of future contract i in phase t: $v_{i,t}$ stands for transaction amount of future contract i in phase t.

Amihud liquidity ratio reflects the reaction degree of futures price fluctuation to transaction amount. The greater Amihud liquidity ratio is, the lower the liquidity is.

10. Martin Liquidity Ratio

Martin liquidity ratio shows price fluctuation caused by a unit volume, which stands for price fluctuation, using the square of price fluctuation.

$$M_t = \sum_{t=1}^{n} \frac{(p_{i,t} - p_{i,t-1})^2}{v_{it}}, \quad (32.10)$$

where M_t stands for Martin liquidity ratio; p_{it} stands for the price of future contract i in t phases; v_{it} stands for trading volume of future contract i in t phases.

The higher Martin liquidity ratio is, the lower liquidity is; conversely, the lower the ratio is, the higher the liquidity is.

11. Hui-Heubel Liquidity Ratio

Hui-Heubel liquidity ratio is similar to Amivest liquidity ratio, but it takes open interest of future contract into account.

$$L_{HH} = [(P_{\max} - P_{\min}) / P_{\min}] / [v / (s \times \bar{p})], \quad (32.11)$$

where $P_{\max}$ stands for the highest value of the highest price of the future contract in five days; $P_{\min}$ stands for the lowest value of the lowest price of the future contract in five days; v stands for total transaction amount in five days; S stands for open interest of future contract; $\bar{p}$ stands for the average future contract price in five days.

The lower Hui-Heubel liquidity ratio is, the higher the liquidity is; conversely, the market liquidity is lower.

Among those eleven indexes, the greater value of the five indexes is-trading volume, open interest, turnover rate, market depth and Amivest liquidity, the higher varieties of liquidity for the futures are; while the smaller value of the six indexes is-price fluctuation index, relative bid-ask spread, effective spread, Amihud liquidity ratio and Hui-Heubel liquidity ratio, the higher varieties of liquidity for the futures are. The reciprocal is taken from the six indexes like price fluctuation index to keep indexes into the same trend.

To avoid being influenced by dimension and data oscillating, those variables should be averagely processed, and the formula for data processing is as follow:

$$X_{ij} = \frac{X_{ij}^0}{\sum_1^n X_{kj}^0 / n}, \quad (32.12)$$

where X_{ij}^0 stands for the ith primary data of the jth index; X_{ij} stands for the dimensionless data equalized by the index stands for the amount of samples.

Then we can get variables as follow:

X_{i1} Trading volume
X_{i2} Positions
X_{i3} Turnover rate

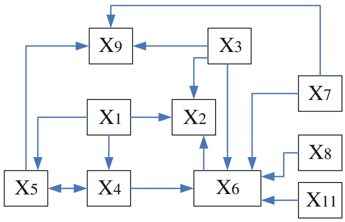

Fig. 32.1 System structure graph of Bond futures liquidity measures

X_{i4} Reciprocal value of price fluctuation index
X_{i5} Reciprocal value of relative ask-bid spread
X_{i6} Reciprocal value of effective spread
X_{i7} Market depth
X_{i8} Amivest liquidity ratio
X_{i9} Reciprocal value of Amihud liquidity ratio
X_{i10} Reciprocal value of Martin liquidity ratio
X_{i11} Reciprocal value of Hui-Heubel liquidity ratio.

32.4.2 Modeling

Model in the compiled OSA process to get five characteristic (output) variables.

X_2 Positions
X_4 Reciprocal value of price fluctuation index
X_5 Reciprocal value of relative ask-bid spread
X_6 Reciprocal value of effective spread
X_{i9} Reciprocal value of Amihud liquidity ratio.

Build GMDH input and output models of those five selected output variables to get:

- $X_2 = 1.351633 + 0.225471X_6 + 0.066567X_1 - 0.643671X_3$. Sum of prediction error square (PESS) = 0.1452, mean absolute percentage error (MAPE) = 6.83 %, approximating variances (AEV) = 0.1204;
- $X_4 = -0.000080 - 0.000003X_1 + 1.000083X_5$, PESS = 0, MAPE = 0 %, AEV = 0;
- $X_5 = 0.000080 + 0.000003X_1 + 0.999918X_4$, PESS = 0, MAPE = 0 %, AEV = 0;
- $X_6 = 0.075799 - 0.004223X_8 - 0.045118X_3 - 0.051620X_7 + 1.077942X_4 - 0.05278\ X_{11}$, PESS = 0.0106, MAPE = 2.86 %, AEV = 0.0099;
- $X_9 = -0.221528 - 0.062831X_7 + 0.111108X_3 + 1.173251X_5$, PESS = 0.0237, MAPE = 4.20 %, AEV = 0.0218.

System structure graph (Fig. 32.1) is drawn according to the model.

32.4.3 Analysis of Model Consequence

Here, the purpose that we choose the linear model is that it is convenient to analyze the influence factors. The fitting error and forecast error of GMDH model we get are both comparatively little, so it is satisfying from a modeling point of view.

As is shown in Fig. 32.1, China's treasury bond futures market's liquidity can be overall reflected by the five indexes-open interest, price fluctuation index, relative bid-ask spread, effective spread and Amihud liquidity ratio. Now we make some analysis from models themselves.

1. Positions. Turnover rate and effective bid-ask spread have negative effects on the positions index, and the former have the most negative influence. When the volume of business is definite, the lower the positions index is, the longer holding time of futures contract is, which means the open interest is bigger. Relative bid-ask spread reflects the balance between order price and the midpoint of selling and purchasing prices when the order arrives. If relatively effective spread is obvious, the price fluctuation is violent and cost of order is high. Therefore, it will have negative influence on the positions index. Volume of business will put positive influence on the positions index but the influence coefficient is small.
2. Price fluctuation index. Relative bid-ask spread has the most positive influence on price fluctuation index. Price fluctuation index stands for immediate transaction's cost. The higher it is, the larger the price fluctuation is. Volume of business will have positive influence on price fluctuation index, but the influence coefficient is small.
3. Relative bid-ask spread. Price fluctuation index will have the most positive influence on relative bid-ask spread. The higher volatility of price fluctuation is, the bigger volume of immediate transactions is. Volume will have negative influence on relative bid-ask spread, but the influence coefficient is small.
4. Relative effective spread. Effective spread reflects the balance between order price and the midpoint of selling and purchasing prices when the order arrives. Price fluctuation index has the biggest positive influence on effective spread. The higher volatility of price fluctuation is the higher actual execution cost is. In addition, turnover rate, market depth and Amivest liquidity ratio also will put positive effect on effective spread while Hui-Heubel liquidity ratio will have negative effect, but the influence coefficient is small.
5. Amihud liquidity ratio. Relative spread will have the biggest positive influence on Amihud liquidity ratio. Amihud liquidity ratio reflects futures price fluctuation's reaction degree to transaction amount. The wider relative spread is, the higher volatility of price fluctuation is and the smaller transaction amount is. That is to say the greater Amihud liquidity ratio is, the lower liquidity is. Turnover rate, which measures the time of holding a future contract, will have negative influence on it. The higher turnover rate is, the bigger transaction amount is; the smaller Amihud liquidity ratio is, the higher liquidity is.
6. Based the analysis of these models, we believe that China's treasury bond futures market's liquidity can be evaluated by using the positions index, the price

fluctuation index, the relative bid-ask spread, the effective spread and Amihud liquidity ratio. Of particular concern are the positions index, the fluctuation of price index and the relative bid-ask spread.

32.5 Conclusion

The article studied the liquidity index system of the treasury bond futures market. Based on the four-dimensional liquidity index, combined with the high frequency data of treasury bonds futures trading and the objective system analysis algorithm, the liquidity of the treasury bond futures market was studied. The research shows that the liquidity of China's treasury bond futures market can be thoroughly measured with the inventory, price fluctuations index, relative bid-ask spread, effective spread and Amihud liquidity ratio.

Acknowledgments The research work was supported by "The Department of Education Key Project of Sichuan Province" under Grant No. 13SA0136 and No. 14SA0013, "Research Team Project of Sichuan Normal University", "The Project of Sichuan Normal University" (14yb18).

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Chapter 33
The Method of Knowledge Chain Partner Selection Based on Improved TOPSIS

Hong Peng and Zongxin Liu

Abstract The defects in knowledge chain partner selection using traditional entropy weight method were found as follows: unscientific in given weight and possibility of two or more enterprises existing in getting the minimum value of distance to the ideal point. An improved TOPSIS model was presented to solve the above problems to select knowledge chain partner. At first, the index weight was given using PPC under subjective preference constraints and built the weight matrix. And then, a kind of brand-new distance coefficient, Variant Chi-square Distance, was presented to replace Euclid distance to calculate the approach degree of each alternative to ideal solution. At last, the optimal partner was determined by the approach degree. In this way, the non-determinacy and randomness resulting from the subjective judgments in the assessment can be avoided, as can the problem that coinstantaneous scheme may be ideal or not, which improves the scientificity and rationality of TOPSIS Model. At the end of this paper, the feasibility and validity of this method were testified by the actual problem.

Keywords Knowledge chain · Partner selection · Projection pursuit · TOPSIS · Variant chi-square distance

33.1 Introduction

With the advent of the era of knowledge economy, more and more companies found that only rely on their own strength is difficult to develop the knowledge and ability required in the process of the production and business operation. Therefore, more and more companies establish strategic partnership with suppliers, customers, universities, research institutes and even competitors, and through knowledge flows between

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_33, © Springer-Verlag Berlin Heidelberg 2014

each other achieve knowledge sharing and knowledge creation, thus forming a chain of knowledge [1].

After Spinello [8] first proposed the concept of knowledge chain, many scholars in this new field carried out research accordingly, and achieved fruitful results [5, 6, 9, 10]. Gu et al. [1] who believes that knowledge chain life cycle is divided into four distinct stages, the gestation period, the formation, the operation and the disintegration, and each stage contains a number of decision-making process. Core business, as a chief for knowledge chain, faces a series of decision problems in different stages of the life cycle of knowledge chain. The choice of partners is one of the important decision-making problems in the formation core business knowledge chain and it is directly related to the success of the knowledge chain. Xiao and Gu [11] make a preliminary study and put forward relevant index system and method based on entropy weight, which is simple and practical and has become a more mainstream knowledge chain partner selection method. However, using this method to select the knowledge chain partners exist the following problems: One is the possibility of two or more enterprises existing in getting the minimum value of distance to the ideal point which increase the uncertainty of judgment [11]; The other is that the combination used in the form of weights may increase the additional information which did not actually get [12]. Therefore, the improved TOPSIS algorithm we proposed to select the knowledge chain partners, not only successfully solved these two problems, but also overcame the shortcomings of traditional TOPSIS method using Euclidean distance, avoided the near-ideal solution and negative ideal solution program and improved the scientificity and adaptation of TOPSIS Method. At the end of this paper, the feasibility and validity of this method were testified by the actual problem.

33.2 Traditional Algorithms and Review for TOPSIS Model

The TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) model, first proposed by Hwang and Yoon in 1981 [2], is a popular program with limited multiple attribute decision analysis. It is based on the nature of indicators and data for collection options to a group of the best indicators of positive ideal solution as a virtual data, with a group of the worst index data as the virtual negative ideal solution, by comparing the solution points from the positive and negative ideal point size of the Euclidean distance to determine the evaluation scheme.

The most obvious difference between the TOPSIS method and the method proposed by Liao and Gu [5] is with the use of both the ideal solution, and the negative ideal solution. Because just using the ideal solution sometimes appears one or two (or more) alternatives with the same distance to the ideal solution. To distinguish the pros and cons of these two programs, we introduce of negative ideal solution and calculate the distance between these two programs and the negative ideal solution, and the program which is far away from the negative ideal solution is better. This completely avoids the problems of the original method. However, there are some

issues about the traditional TOPSIS method, mainly in the following two aspects [3]:
(1) Traditional TOPSIS method is based on Euclidean distance to determine the degree of scheme close to the ideal solution, not only exists the problem, evaluation index information repeated impacting assessment results, and may also occur in practice that the ideal solution scheme and negative ideal solution of Euclidean distance near the Euclidean distance is same, so that it cannot fully reflect the advantages and disadvantages of each scheme.
(2) Traditional TOPSIS method for evaluation index weights commonly uses the subjective weighting method, such as expert evaluation, AHP. Although this empowerment approach can reflect the experiences and opinions of experts, to some extent, more subjective factors, too much rely on subjective judgment of policy makers, and often do not reflect the actual evaluation index, existing irrationality and unfairness.

33.3 Improvement of TOPSIS Algorithm

Aiming at the shortcomings of the traditional TOPSIS method, this paper carries on the improvement. First, determine the evaluation index weight through projection pursuit method under the constraint of subjective preference right. The second is to introduce the idea of chi-square test, propose a new distance coefficient, Variant Chi-square Distance, to calculate the closeness to the ideal solution instead of Euclidean distance and determine the ordering for scheme sets.

1. Establish Standard Decision Matrix

Establish standard sample $\tilde{X}$ then after a dimensionless processing, form the multi-attribute decision making (MADM) problems' solution sets $\{M(i)|i = 1, 2, \cdots, n\}$ and index sets $\{C(j)|\, j = 1, 2, \cdots, m\}$. The index corresponding to solution $M(i)$ is $C(j)$ and the value of $C(j)$ is $x^*(i, j), i = 1, 2, \cdots, n, j = 1, 2, \cdots, m$. So a multi-attribute decision making problems can be described by standard decision matrix X as follows:

$$\mathrm{X} = \begin{bmatrix} x^*(1,1) & x^*(1,2) & \cdots & x^*(1,m) \\ x^*(2,1) & x^*(2,2) & \cdots & x^*(2,m) \\ \vdots & \vdots & \ddots & \vdots \\ x^*(n,1) & x^*(n,2) & \cdots & x^*(n,m) \end{bmatrix}. \tag{33.1}$$

$$\text{For positive indexes: } x^*(i, j) = \frac{x(i, j) - x(\min, j)}{x(\max, j) - x(\min, j)}, \tag{33.2}$$

$$\text{For negative indexes: } x^*(i, j) = \frac{x(\max, j) - x(i, j)}{x(\max, j) - x(\min, j)}, \tag{33.3}$$

where, $x(i, j)$ is the initial numerical of ith ($i = 1, 2, \cdots, n$) sample's jth ($j = 1, 2, \cdots, m$) index; $x(\max, j)$ is jth index's minimum and maximum.

2. Building Weighted Decision Matrix

There are two main types of method to determine the weighing values of evaluation indexes. One is the subjective weighting method, which uses qualitative expert advice rating method to determine the weights. The other is an objective method, that is, according to the relationship between each index or the variation degree of all kinds of indexes to determine the weight. In order to be accurate, objective and reasonable for the empowerment of each evaluation index, this paper combines the above two methods of empowerment and improve the projection pursuit model through the study of the subjective preferences of global optimization of the process constraint and thus determine the weights of evaluation indexes.

(1) Projection Pursuit Method Based on Initiative Preference Restraint

Projection pursuit is projects high dimensional data set to low dimensional space to reveal the internal structures and characters of high dimensional data; it's a statistical method to deal with multi-factor complex issue [1]. The basic idea is that, according to application background, define a projection index function to measure the possibility for revealing a sort of classification structure of projection. Then project high dimensional data to lower dimensional (1-3 dimension, achieve to reduce dimensionality, and make it close to actually application background). Among them, the major thing that people were interested in was the direction to make index function reach maximum, also known as best projection direction. It can reflect the degree of importance for variables, and we can give an objective weight of evaluation index. While, the objective weight is got from analysing data's variance, it cannot totally reflect the feature of index attribute, and even almost appear completely opposite with expertise. So, we improve it, adding some constraints when we solve projection function maximize problem, then it can find global optimization based on people's preference. This practice can guarantee receive a more rational assigning result, conform to index properties' feature. Detail method of work follows:
(a) experts determine the range of index weight

At present, almost ensure subjective weight by Experts Mark, Analytic Hierarchy Process (AHP), Delphi method and so on. As to expert, estimating the property weight exists stochastic uncertainties more or less, and this kind of uncertainties is almost from uncertainty of the accuracy of judgment. So, it's uneasy for expert to give a certainly weight through judge. The relatively easier way is use interval weight and region weight also suit people usual practice. Meanwhile, when expert give a preference information or fuzzy evaluation, changing it into interval weight is more scientific comparing with certainly weight. So, the model of subjective weight employing interval number as follows: $\tilde{v} = [(v_1^l, v_1^u), (v_2^l, v_2^u), \cdots, (v_m^l, v_m^u)]$, where $v_1^l < v_1^u$; $\sum_{j=1}^{m} v_j^l \leq 1$; $\sum_{j=1}^{m} v_j^u \geq 1$.

(b) building projection index function

Applies dimensionless method by way of Eqs. (33.2) and (33.3) to evaluated object index coordinate values, and apply same process to ideal standard sample forming m dimension data $\{x^*(i, j)|\, j = 1, 2, \cdots, m\}$, combine 2 data to forming a one-dimensional projection value $z(i)$ projection direction by $a = \{a(1), a(2), a(3), \cdots, a(m)\}$ (when evaluated object changed, should count after re-integrating $\{x^*(i, j)|\, j = 1, 2, \cdots, m\}$: $z(i) = \sum_{j=1}^{p} a(j)x^*(i, j), (i = 1, 2, \cdots, n)$. Among the formula, a is vector of unit length.

Then, build projection index functions $Q(a)$: $Q(a) = S_z D_z$, where S_z is standard deviation of projection $Z(i)$, and D_z is topo-density of projection $Z(i)$, namely:

$$S_z = \sqrt{\frac{\sum_{i=1}^{n}[z(i) - E(z)]^2}{n-1}}, \quad D_z = \sum_{i=1}^{n}\sum_{j=1}^{n}[R - r(i, j)] \cdot u[R - r(i, j)], \quad (33.4)$$

where, $E(z)$ is AVG of sequence $\{z(i)|i = 1, 2, \cdots, n\}$ and R is window radii of topo-density. We can confirm R by test, usually choosing $0.1S_z$. $r(i, j)$ means distance between samples, $r(i, j) = |z(i) - z(j)|$. $u(t)$ is unit phase step function; if $t > 0$, it equals to 1; if $t < 0$, its value is 0.

(c) global optimization based on artificial fish swarm algorithm

The basic idea of artificial fish swarm algorithm is that, on a water area, fishes usually grow in nutrients rich region, and based on this feature, fish swarm algorithm build artificial fish to imitate fishes' actions, such as foraging, cluster, tailgate and so on, to achieve global optimization. Li and Shao [4] choose multi-passageway parallel structure based on behavior to build man-made fish model, and this model encapsulated artificial fish's status and pattern of behavior. An algorithm is adaptive behavior of artificial fish individual activities, and individual activities is once iteration of the algorithm.

The state of artificial fish can be described by vector as $X = (x_1, x_2, \cdots, x_n)$, and $x_i (i = 1, 2, \cdots, n)$ is controlled variable to optimize; the currency situation food density of artificial fish is $F = f(X)$; the distance of each artificial fish is $d_{ij} = \|X_i - X_j\|$, equaling to two-norm of vector $(X_i - X_j)$; Visual expresses perception distance of artificial fish; Step expresses maximum of size of remove for artificial fish step; δ expresses crowd degree factor; N shows number of artificial fish participating in optimizing, called group scale [7]. The basic mathematical description of artificial fish algorithm could refer to literature [4].

Using artificial fish algorithm solve projection index function maximization problem, to estimate the optimal projection direction, namely the maximizing the objective function is:

$$\max : Q(a) = S_z D_z \quad (33.5)$$

The constraint is:

$$\text{s.t.} \sum_{j=1}^{p} a^2(j) = 1, \tag{33.6}$$

$$v_j^l \le a^2(j) \le v_j^u, \tag{33.7}$$

where, Eq. (33.7) is the constraint conditions based on subjective preferences. The best projection direction a is: $a = [a(1), a(2), \cdots, a(m)]$. At last, according to the value of the optimal projection direction a we can get weight $w(j)$ namely $w(j) = [a^2(1), a^2(2), \cdots, a^2(m)]$.

(2) Building Weighting Matrix

Multiply standardization decision matrix $\mathbf{X} = x^*(i, j)_{m\times n}$ and weight $w(j) j = 1, 2, \cdots, m$ together, and get the weight decision matrix $\mathbf{R} = r(i, j)_{m\times n}$: $r(i, j) = w(j) \times x^*(i, j), i = 1, 2, \cdots, n, j = 1, 2, \cdots, m$.

1. The Calculation Approaching $M(i)$ of Chi-square Distance Variation

According to the established weight decision matrix, the optimal and worst vector based on its columns maximum and minimum values respectively record as following:

$$\mathrm{R}^+ = [r(\max, 1), r(\max, 2), \cdots, r(\max, m)],$$
$$\mathrm{R}^- = [r(\min, 1), r(\min, 2), \cdots, r(\min, m)].$$

The traditional TOPSIS method is based on Euclidean distance to determine the degree of solution close to the ideal solution. As a result of the Euclidean distance metric is the real distance of two point on m dimensional space, but the case close to ideal Euclidean distance solution may also close to Euclidean distance of negative ideal solution in the actual. To avoid this defect, this paper abandons the traditional thinking, and introducing the idea of chi-square test (20). Assumes that the solution set and ideal solution (or negative ideal solution) are random variables from the same overall, and calculate the two random variables' expectations in the same overall assumptions and judge the consistency of two solution sets by observing random variables and the deviation degree of expectations got from the assumptions. The smaller Chi-square value is, the more likely pass the assumption get form the same overall; the consistency of two data is more stronger, and two schemes have higher proximity. Conversely, the bigger Chi-square value is, the less likely pass the assumption and get from the same overall; the consistency of two data is more weaker, and two schemes have lower proximity. To distinguish the original chi-square coefficient, here we define the chi-square value vividly as Variant Chi-square Distance. In fact, the mutation of chi-square distance metric is not the traditional sense of "distance" like Euclidean distance, while its measurement is the accumulation of the ratio of square of difference of random variable and its expected value, and its expected value, which is the dispersion degree of random variable and its expected value. Choose Chi-square distance replace Euclidean distance to judgment the degree of scheme close to the ideal solution, and its solution and the variation chi-square distance of positive and negative ideal solution are following:

$$D^{+}(i) = \sum_{j=1}^{m} \left\{ \frac{\left[r(i,j) - e^{+}(i,j)\right]^2}{e^{+}(i,j)} + \frac{[r(\max,j) - e(\max,j)]^2}{e(\max,j)} \right\}, \quad (33.8)$$

$$D^{-}(i) = \sum_{j=1}^{m} \left\{ \frac{\left[r(i,j) - e^{-}(i,j)\right]^2}{e^{-}(i,j)} + \frac{[r(\min,j) - e(\min,j)]^2}{e(\min,j)} \right\}, \quad (33.9)$$

where,

$$e^{+}(i,j) = \frac{r(i,j) \times \sum_{i=1}^{n} r(i,j)}{\sum_{j=1}^{m} r(i,j) + \sum_{j=1}^{m} r(\max,j)}, \quad e^{-}(i,j) = \frac{r(i,j) \times \sum_{i=1}^{n} r(i,j)}{\sum_{j=1}^{m} r(i,j) + \sum_{j=1}^{m} r(\min,j)},$$

$$e(\max,j) = \frac{r(\max,j) \times \sum_{i=1}^{n} r(i,j)}{\sum_{j=1}^{m} r(i,j) + \sum_{j=1}^{m} r(\max,j)}, \quad e(\min,j) = \frac{r(\min,j) \times \sum_{i=1}^{n} r(i,j)}{\sum_{j=1}^{m} r(i,j) + \sum_{j=1}^{m} r(\min,j)}.$$

Compare with Euclidean distance using chi-square distance variation to judge the degree of scheme close to the ideal solution have two advantages:

- TOPSIS model cannot solve the evaluation information repeat problem being from evaluation index correlation, so choose of indicators deeply impact on the evaluation results. Variation Chi-square distance made a corresponding processing for information repeatability when solving expectations. It is not only considering the relationship between different variables under the same indexes, but also considers the relationship between indexes. Compare with Euclidean distance, this distance has overcome the correlation between indexes, and improved the resolution of the model.
- Variation chi-square distance is the ratio of square of difference of random variable and its expected value, and it is the dispersion degree of random variable and expectations. The expectations of the same random variables in different overall distribution are also different. When we solve the variation chi-square value according to scheme and the positive and negative ideal solution, due to the great differences between positive and negative ideal solution, the expectations can have enormous differences, and obtaining the variation of chi-square value is impossible the same. Specific proof as follows:
  Assuming that:

$$\alpha = \frac{\sum_{i=1}^{n} r(i,j)}{\sum_{j=1}^{m} r(i,j) + \sum_{j=1}^{m} r(\max,j)}, \quad \beta = \frac{\sum_{i=1}^{n} r(i,j)}{\sum_{j=1}^{m} r(i,j) + \sum_{j=1}^{m} r(\min,j)}.$$

Because:

$$\sum_{j=1}^{m} r(\max, j) > \sum_{j=1}^{m} r(\min, j). \quad \text{So, } \beta > \alpha, 1-\alpha > 1-\beta.$$

Because:

$$\begin{aligned}
&\left\{\frac{\left[r(i,j)-e^{+}(i,j)\right]^2}{e^{+}(i,j)}+\frac{[r(\max,j)-e(\max,j)]^2}{e(\max,j)}\right\}\\
&\quad-\left\{\frac{\left[r(i,j)-e^{-}(i,j)\right]^2}{e^{-}(i,j)}+\frac{[r(\min,j)-e(\min,j)]^2}{e(\min,j)}\right\}\\
&=\left\{\frac{[r(i,j)-r(i,j)\times\alpha]^2}{r(i,j)\times\alpha}+\frac{[r(\max,j)-r(\max,j)\times\alpha]^2}{r(i,j)\times\alpha}\right\}\\
&\quad-\left\{\frac{[r(i,j)-r(i,j)\times\beta]^2}{r(i,j)\times\beta}+\frac{[r(\min,j)-r(\min,j)\times\beta]^2}{r(\min,j)\times\beta}\right\}\\
&=\frac{\beta\times(1-\alpha)^2\times[r(i,j)+r(\max,j)]-\alpha\times(1-\beta)^2\times[r(i,j)+r(\min,j)]}{\alpha\times\beta}>0.
\end{aligned}$$

Therefore: $D^{+}(i) > D^{-}(i)$.

So we can ensure that, in the TOPSIS model use the variation chi-square to calculate the distance of scheme and the ideal solution, and it is always greater than the distance of scheme and the negative ideal solution. So we can avoid scheme close to the ideal solution and also close to negative ideal solution by using Euclidean distance.

According to the calculated chi-square distance variation, the proximity degree of the $M(i)$ and the optimal scheme is:

$$H(i) = \frac{D^{-}(i)}{D^{+}(i) + D^{-}(i)}. \tag{33.10}$$

2. Decision Making

Rank according to the proximity degree of $M(i)$ and the optimal scheme. The optimal solution is while $H(i)$ gets maximum value, that is, the partner we should choose.

33.4 Emulation Analysis

1. Standard Decision Making Matrix

We take the data in the literature by Liao and Gu [5] for an example. Assumes that the core enterprise tries to choose one of four companies as their partner, and through carefully evaluating of the four enterprises, and normalization, we get the following evaluation matrix:

$$X = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 & 0.333 & 0 \\ 0.667 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0.5 & 1 & 1 & 0.6 & 0.667 & 1 \\ 0.333 & 1 & 0 & 0.75 & 1 & 1 & 0.5 \end{bmatrix}.$$

2. Combination Weighting

(1) The Subjective Preference Constraints

According to the evaluation index proposed by Liao and Gu [5] the experts by their experience determine the subjective weight of various indicators. $W = [(0.08, 0.12), (0.07, 0.11), (0.08, 0.12), (0.20, 0.30), (0.180.21), (0.16, 0.19), (0.14, 0.17)]$.

(2) Using Artificial Fish Swarm Algorithm to Solve Weights

Enter data into the projection pursuit classification model under the restriction of subjective preference. Using MATLAB programming, and select some in the AFSA optimization process: $Visual = 0.3, \delta = 0.3, N = 30, K = 100$. After running the program under the MATLAB, get the best projection direction, $a = [0.282, 0.264, 0.283, 0.489, 0.447, 0.424, 0.387]$. Determine the weight of the final, $V = [0.079, 0.069, 0.080, 0.239, 0.225, 0.179, 0.149]$.

3. Calculate the Closeness

Accordance to the Eq. (33.10), get $H(1) = 0.2713$, $H(2) = 0.5164$, $H(3) = 0.6939$, $H(4) = 0.7075$. Because the value of $H(4)$ is the maximum, the core enterprise should choose number 4 as a partner.

33.5 Conclusion

How to scientifically and rationally choose core enterprise partner is directly related to the success or failure of the chain of knowledge. In order to solve the defects in knowledge chain partner selection using traditional entropy weight method, such as unscientific in given weight, possibility of two or more enterprises existing in getting the minimum value of distance to the ideal point, this paper presented TOPSIS model. This method not only in the process of empowerment fully plays the advantages when Projection Pursuit process high-dimensional data, but also absorbs expert experience by subjective preference constraints, which avoids using only the objective weight to cause of the contrary of defined weight and the actual importance of property to happen. The introduction of a negative ideal solution and the variation of the chi-square distance effectively improve the resolving power of the model, and make the results more scientific. The application shows that the improved TOPSIS model presented in this paper is effective and workable which provides a new way of thinking to solve these problems.

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Chapter 34
A Relationship Model of Brand Marketing Strategy and Agribusiness Dynamic Capability

Yu Ding, Wensheng Li and Yi Peng

Abstract The influencing way of agribusiness dynamic capability on brand marketing strategy is discussed with concept of absorptive capability. Literature investigation and brain-storm are adopted in theoretical model construction and proposition of nine hypotheses that proved by empirical analysis. The result shows agribusiness dynamic capability influences brand marketing strategy with absorptive capability as mediation to some degrees. The absorptive capability of agribusiness could be improved by enhancing knowledge recognition ability, knowledge assessment ability, knowledge digestion ability and knowledge application ability so as to improve the level of brand marketing strategy.

Keywords Agribusiness · Absorptive capacity · Dynamic capability · Brand marketing strategy · Empirical analysis

34.1 Introduction

Research on influence of dynamic capability on agribusiness brand marketing strategy has attracted attention in academic circle. At present, brand marketing strategy is not only activities done by people in marketing sections but also develops into comprehensive competition of resources and capabilities.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_34,

As current research shown, dynamic capability influences the activities and marketing strategy of enterprises. However, influencing way and mechanism of dynamic capability on marketing strategy, is it direct or indirect influence and by which way it influences are not revealed in current research.

So in this paper, we tries to explore influencing way and mechanism of dynamic capability on brand marketing strategy with concept of absorptive capability, explain the influence of dynamic capability on absorptive capability and the influence of absorptive capability on marketing strategy as well as reveals the function of absorptive capability in influence process. The conclusion will help enterprise to improve the level of brand marketing strategy with improving its absorptive capability by enhancing dynamic capability.

34.2 Literature Review

Dynamic Capability of Enterprises: According to the resource-based view proposed by Barney [2, 3] and Amit and Schoemaker [1], competitive advantages of agribusiness are from valuable, scarce, inimitable and irreplaceable resources and capabilities. The idea of dynamic capability proposed by Priem and Butler [13] and Teece and Pisano [18] makes up the defects and extends the connotation of resource-based view. The idea of dynamic capability has been widely accepted as a new idea since Teece et al. [19] defined dynamic capability as ability of integrating, establishing and resetting internal and external resources of enterprises to cope with rapid change of environments. Dynamic capability is emphasized on environmental changes, protracted nature, dynamic and heterogeneity,which influences brand marketing. And that is proved by study of many scholars including Teece and Pisano [18], Teece et al. [19], Eisenhardt and Martin [7], Teece [16], Zollo and Winter [24], Winter [20], Zahra et al. [23], Helfat et al. [9] and Teece [17].

Dynamic capability stresses that enterprises should make use of resources and abilities to adapt to changes of external environment. Marketing strategy is taking advantage of resources and abilities of enterprises to achieve maximum profits and marketing performance on the basis of changing market, that corresponds with the aim of dynamic capability. Eisenhardt and Martin [7], King and Tucci [11], Song et al. [15], Danneels [5] and Teece et al. [19] argue that dynamic capability is of great significant importance to explain competitive advantage of enterprises while other scholars such as Zott [25] and Zahra et al. [23] hold the different opinion.

As the above study shown, dynamic capability has effect on internal activities and marketing strategy. But the specific influencing way and mechanism, namely, is it direct or indirect influence, through which way still needs further research.

Dynamic Capability of Agribusiness: According to research, dynamic capability refers to unique resources owned by agribusiness and ability of coping with rapid changing environment.

In the light of resource-based view raised by Barney [2, 3], this article argues that land resources, farmers' resources, human resources and social capital are elements form resources and abilities of agribusiness. All these elements are concerned with the existing and developing of agribusiness and difficult to copy due to the uniqueness. How to cope with rapid changing environment by making use of resources and capabilities is the core content of agribusiness dynamic capability. Considering characteristics of agribusiness, we believe that ability of coping with rapid changing environment with resources and capabilities mainly embodied in market strain capability, capability of resources integration and reforming of group policies on the basis of study by Teece [16, 17, 19] and relevant researches.

The Influencing Mechanism of Agribusiness Dynamic Capability on Brand Marketing Strategy: The theory of consumer behavior reveals consumer behavior is a continuous process. That determines agribusiness brand marketing is a systematic and continuous process, in which comprehensive and sustainable resources and capabilities as well as dynamic capability are necessary.

As strategic integration of communication channels in marketing process, integrated marketing communication-IMC has appeared since 1980s. It is a systematic project that involves integrating resources including marketing, strategy, finance and technology. Namely, dynamic capability affects choice and practice of brand marketing strategy by influencing integration extent and degree of brand marketing.

Based on brand marketing theory put by Shen and Hu [14] and environment analysis of agribusiness development, it is believed four strategies are suitable for agribusiness brand marketing including brand image strategy, brand location strategy, brand extension strategy and brand relations strategy. These four strategies will promote brand marketing from different aspects.

Brand image strategy mainly focuses on dynamic changing image of agribusiness and it influences the minds of consumers. Therefore, it is necessary for agribusiness to constantly update its brand image. Taking advantage of market strain capability, agribusiness can promptly spot the changes in consumers' recognition of brand image and consumers' preferences for the new brand image. Based on that, resource integrating and group policies transforming are involved in updating brand image according to the preferences of consumers.

The core of brand location strategy lies in the perfect match of brand location and target consumer groups. As consumers' demand has the characteristics of dynamic change, it is vital for agribusiness to find out changes of consumer demands timely through market orientation and meet the changing needs of consumers on the basis of market strain ability, integrating the resources of agribusiness and transforming group policies of agribusiness.

Brand extension strategy is a behavior of benefits and risks. Due to the dynamic nature of brand awareness for agribusiness, it is necessary for agribusiness to grasp the consumers' perception of the corporate brand so as to adjust its brand extension strategy in time with market strain ability. This is a systematic project, which involves consumer information, new product development and marketing strategy. So agribusiness needs to integrate various resources, reform group policies at the same time so as to earn more profits and avoid risks in the implementation of the brand extension strategy.

Brand relations strategy is mainly dealing with the relationship between brand and brand, consumer and brand, product and brand, marketer and brand, other stake holders and brand, etc. With market strain ability, agribusiness could grasp the information of consumers and competitors in time. Through integrating resources and reforming group policies, they could adjust the method of brand relations and make a better choice of brand relations strategy.

Absorptive Capability: Absorptive Capability has developed into a relatively mature academic concept. Lane et al. [12] believes absorptive capability is in close connection with knowledge acquisition, digestion and application as one of core abilities to acquire and keep competitive advantages. Cohen and Levinthal [4] believes that absorptive capability refers to recognition, assessment, digestion and application of external knowledge resources. And absorptive capability of agribusiness is congregation of staff's absorptive capability. On the basis of dynamic capability view put by Teece [16], extending the view of Cohen and Levinthal [4], Zahra and George [22] believes absorptive capability is practice and process of acquiring, digesting, transforming and applying knowledge resources to form dynamic capability. Emphasizing on future development of enterprises, Lane et al. [12] raises that absorptive capability is double ability of carrying out exploratory identification, evaluation and mastering new valuable knowledge from the external as well as applying knowledge by learning and digesting to create new knowledge in different situations.

Focusing on application of knowledge acquisition and digestion, Cohen and Levinthal [4] together with Lane et al. [12] suggest absorptive capability could be evaluated from three dimensions including recognition and assessment, digestion, application. While Zahra and George [22] raise the view of four-dimension measurement (acquisition, digestion, conversion, application) and emphasize on knowledge conversion of enterprises by distinguishing conversion from digestion. It is common to see idea of three-dimension in existing documents but some scholars such as Jansen et al. [10], Fosfuri and Tribo [8], Yeoh et al. [21] tend to use four-dimension in recent years.

Absorptive Capability of Agribusiness: On the basis of relative research, we believe absorptive capability refers to recognition, assessment, digestion and application of internal and external knowledge resources. According to view of Cohen and Levinthal [4], agribusiness absorptive capability mainly refers to absorptive capability congregation of the staff. So the study is based on individual absorptive capability and mainly discusses the influence of individual absorptive capability on relevant activities of agribusiness. The agribusiness will have capability of recognizing, assessing, digesting and applying resources only when the staff of agribusiness have it. In other words, if dynamic capability can not be recognized, assessed, digested and applied, it will not be reflected in concrete operation of agribusiness and taken into full play. That is not only real reflection of objective situation but also of great research value to agribusiness.

34.3 The Intermediary Role of Agribusiness Absorptive Capability

The great influence of dynamic capability on four brand marketing strategy combinations has been proved by study of Yu et al. [6]. What is the influencing way and mechanism? By introducing concept of agribusiness absorptive capability, we try to describe the influence of dynamic capability on absorptive capability and the influence of absorptive capability on brand marketing strategy.

Dynamic capability refers to ability to acquire unique resources, cope with market strain, resources integrating and transform group policies that needs the staff's participation.The participating process is also a learning process. According to the opinion of Lane et al. [12], absorptive capability stands for ability to exploratory and applied study ability in different situations. Thus, it is believed dynamic capability has effect on absorptive capability of the staff in this paper. And the following hypothesis is proposed:

Hypothesis 1 The dynamic capability of agribusiness has an important effect on absorptive capability;

According to view of Cohen and Levinthal [4], we believe absorptive capability refers to ability of recognition, assessment, digestion and application of resources as well as absorptive capability congregation of the staff. Therefore, the absorptive capability of agribusiness is the congregation of the staff's absorptive capability. The staff participate in drawing and applying of brand marketing strategy by recognizing, assessing, digesting and applying internal as well as external resources so as to make brand marketing strategy more suitable for market environment. We believe the absorptive capability has effect on brand marketing strategy and propose the following hypotheses.

Hypothesis 2 The absorptive capability of agribusiness has an important effect on brand image strategy;

Hypothesis 3 The absorptive capability of agribusiness has an important effect on brand location strategy;

Hypothesis 4 The absorptive capability of agribusiness has an important effect on brand extension strategy;

Hypothesis 5 The absorptive capability of agribusiness has an important effect on brand relations strategy;

How does dynamic capability affect brand marketing strategy? On the basis of literature review and analysis, we believe dynamic capability affects absorptive capability of the staff. Then the absorptive capability of staff influences on drawing of brand marketing strategy. Namely, absorptive capability plays a bridge role in dynamic capability and brand marketing strategy. Base on the above, the following hypotheses are proposed:

Hypothesis 6 The absorptive capability of agribusiness plays an intermediary role in dynamic capability and brand image strategy;

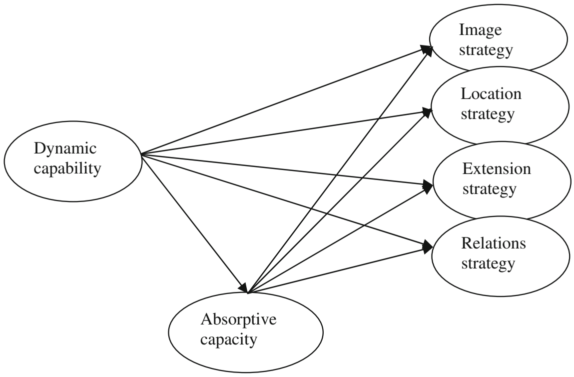


Fig. 34.1 The relationship theoretical model of agribusiness dynamic capability and brand marketing strategy with introduction of absorptive capability

Hypothesis 7 The absorptive capability of agribusiness plays an intermediary role in dynamic capability and brand location strategy;

Hypothesis 8 The absorptive capability of agribusiness plays an intermediary role in dynamic capability and brand extension strategy;

Hypothesis 9 The absorptive capability of agribusiness plays an intermediary role in dynamic capability and brand relations strategy;

34.4 The Relationship Theoretical Model of Agribusiness Dynamic Capability and Brand Marketing Strategy with Introduction of Absorptive Capability

The role of agribusiness absorptive capability in influencing process of dynamic capability on four marketing strategy-combination is stated as the above and the theoretical model of agribusiness dynamic capability and brand marketing strategy is constructed (Fig. 34.1).

34.5 Large Sample Analysis

34.5.1 Measurement of Variables

According to the relative documents and research features, index system of theoretical model is constructed by revising and developing existing scales.

Dynamic capability: Based on relative definition of dynamic capability and research features, the paper argues that four indexes including unique resources, market strain ability, resources integration ability and group policies reforming ability should be taken into consideration in measuring dynamic capability.

Absorptive Capability: On the basis of relative definition of absorptive capability, this paper argues that identification ability, evaluation ability, digestion ability and application ability should be considered in measuring absorptive capability.

Brand Image Strategy: According to the connotation and function of brand image strategy, the paper argues that function image, experiencing image and symbol image are included in measuring brand image strategy.

Brand Location Strategy: According to the connotation and function of brand location strategy, the paper argues that objective market division, product differentiation and price difference should be taken into consideration in brand location strategy measuring.

Brand Extension Strategy: According to the connotation and function of brand extension strategy, the paper argues that brand popularity, product diversification and product correlation should be taken into consideration in brand extension strategy measuring.

Brand Relations Strategy: According to the connotation of brand relations strategy, the paper argues that relation between brand and consumers, the relation between brand and products, the relation between brand and brand, the relation between brand and stakeholders should be taken into consideration in brand relations strategy measuring.

34.5.2 Design, Issuring and Taking-Back of Questionnaire

Theoretical dimensions of measuring variables are deducted and concluded with literature research. The following variables including brand image strategy, brand location strategy, brand extension strategy, brand relations strategy, dynamic capability and absorptive capability are measured in model. The measuring scale is made on the basis of existing scales and actual situation of the study.

Relative experts have been invited to modify the description of specific measuring items after the primary design is finished. Trial test is done among twenty relevant people and correction on the basis of trial test to improve the validity of questionnaire.

296 people from 37 different agribusiness from different areas are chosen for investigation, with 8 people from different departments including strategy planning, production and marketing departments. The effective recovery is 87.2 % with 296 questionnaires delivered, 277 returned, 19 invalid and 258 valid.

SPSS 17.0 and AMOS 7.0 are adopted in data analysis. SPSS 17.0 is mainly used for sample descriptive statistics, correlation analysis and factor analysis. While AMOS 7.0 is mainly for confirmatory factor analysis and path analysis.

Table 34.1 Correlation analysis of the main variables

	1	2	3	4	5	6
Dynamic capability	1					
Absorptive capacity	0.359**	1				
Image strategy	0.325**	0.527**	1			
Location strategy	0.334**	0.331**	0.346**	1		
Extension strategy	0.251**	0.252**	0.296**	0.304**	1	
Relations strategy	0.377**	0.412**	0.360**	0.293**	0.208**	1
Mean	5.36	5.06	5.14	5.31	4.90	5.01
Variance	0.67	0.65	0.65	0.62	0.74	0.70

**Indicates significant on the $p < 0.01$'s level

34.5.3 Descriptive Statistics of Large Samples

In order to get representative samples, enterprises of uniform scale are chosen in sample survey, male accounts 75.2 % of the overall, people aged below 35 accounts 79.1 %, bachelors and masters occupy 80.2 %. That is consistent with features of gender, youth, and education level. People from marketing department account for a half, which is in conformity with marketing subject and position forming as well as provide reasonable data for the study. Considering features of industries, food industry accounts for 43 %. That is relative with marketing as marketing of food industry is representative.

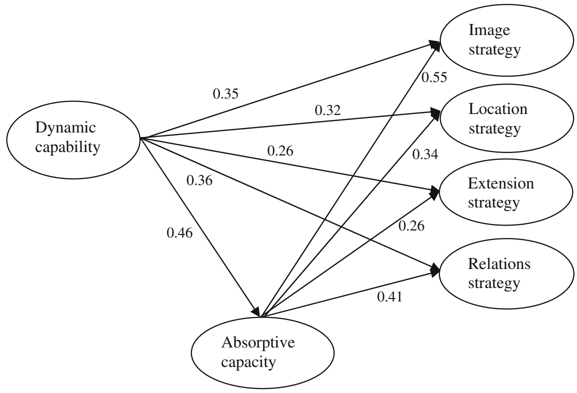
34.5.4 Correlation Analysis

As Table 34.1 shown, the correlation coefficient of main variables including dynamic capability, absorptive capability, image strategy, location strategy, extension strategy, relations strategy is significant on the level of $p < 0.01$. That indicates the correlation of variables is better and needs further analysis.

34.5.5 Factor Analysis

SPSS 17.0 is used for exploratory factor analysis and results are: KMO is 0.873, Bartlett hemisphere inspection is significant on the level of $p < 0.01$. That indicates data is suitable for factor analysis. 33 measurement items are analyzed into 8 principal component factors with exploratory factor analysis. Confirmatory factor analysis is done with AMOS 7.0 to test reliability and validity of exploratory factor analysis. As exploratory factor and confirmatory factor analysis shown, the questionnaire is of good validity with factors loading of concepts are bigger than 0.5. The result of

Fig. 34.2 Path analysis of absorptive capacity's intermediary function



reliability analysis shows cronbachof each concept is greater than 0.7, which means the questionnaire is reliable.

34.5.6 Path Analysis

The intermediary role of absorptive capability between dynamic capability and brand marketing strategy is studied by path analysis with AMOS 7.0 (Fig. 34.2).

Fitting indexes of model 1, χ^2 is 274.597, df is 176, χ^2/df is 1.560, $RMSEA$ is 0.047, GFI is 0.907 and CFI is 0.944. That suggests fitting indexes are in conformity with requirements of structure equation model. The path coefficient of dynamic capability and absorptive capability is 0.46 and is more remarkable when $p < 0.01$ proving Hypothesis 1. The path coefficient of absorptive capability and image strategy is 0.55 and is more remarkable when $p < 0.01$ proving Hypothesis 2. The path coefficient of absorptive capability and location strategy is 0.34 and more remarkable when $p < 0.01$ proving Hypothesis 3. The path coefficient of absorptive capability and extension strategy is 0.26 and more remarkable when $p < 0.05$ proving Hypothesis 4. The path coefficient of absorptive capability and relations strategy is 0.41 and more remarkable when $p < 0.001$ proving Hypothesis 5.

The path coefficient of dynamic capability and image strategy is 0.35 and more remarkable when $p < 0.001$ with introduction of absorptive capability as intermediary variable. However, the path coefficient of dynamic capability and image strategy is 0.67 and more remarkable when $p < 0.001$ without introduction of absorptive capability as intermediary variable. That shows the path coefficient of dynamic capability and image strategy is smaller with introduction of absorptive capability and suggests partial intermediary role of absorptive capability, proving Hypothesis 6.

The path coefficient of dynamic capability and location strategy is 0.34 and more remarkable when $p < 0.01$ with introduction of absorptive capability as intermediary variable. However, the path coefficient of dynamic capability and location strategy is 0.59 and more remarkable when $p < 0.001$ without introduction of absorptive capability as intermediary variable. That shows the path coefficient of dynamic capability and location strategy is smaller with introduction of absorptive capability and suggests partial intermediary role of absorptive capability, proving Hypothesis 7.

The path coefficient of dynamic capability and extension strategy is 0.26 and more remarkable when $p < 0.05$ with introduction of absorptive capability as intermediary variable. However, the path coefficient of dynamic capability and extension strategy is 0.46 and more remarkable when $p < 0.001$ without introduction of absorptive capability as intermediary variable. That shows the path coefficient of dynamic capability and extension strategy is smaller with introduction of absorptive capability and suggests partial intermediary role of absorptive capability, proving Hypothesis 8.

The path coefficient of dynamic capability and relations strategy is 0.41 and more remarkable when $p < 0.001$ with introduction of absorptive capability as intermediary variable. However, the path coefficient of dynamic capability and relation strategy is 0.66 and more remarkable when $p < 0.001$ without introduction of absorptive capability as intermediary variable. That shows the path coefficient of dynamic capability and relations strategy is smaller with introduction of absorptive capability and suggests partial intermediary role of absorptive capability, proving Hypothesis 9.

34.6 Conclusions

Theoretical model of agribusiness dynamic capability and brand marketing strategy is constructed with absorptive capability and nine hypotheses are proposed in this paper. And nine hypotheses are proved by large sample analysis.

The conclusions are:

1. Agribusiness dynamic capability has effect on absorptive capability;
2. Agribusiness absorptive capability has effect on brand image strategy;
3. Agribusiness absorptive capability has effect on brand location strategy;
4. Agribusiness absorptive capability has effect on brand extension strategy;
5. Agribusiness absorptive capability has effect on brand relations strategy;
6. Agribusiness absorptive capability plays a partial intermediary role in dynamic capability and brand image strategy;
7. Agribusiness absorptive capability plays a partial intermediary role in dynamic capability and brand location strategy;
8. Agribusiness absorptive capability plays a partial intermediary role in dynamic capability and brand extension strategy;
9. Agribusiness absorptive capability plays a partial intermediary role in dynamic capability and brand relations strategy.

The partial intermediary role of absorptive capability shows dynamic capability could affect brand marketing strategy by absorptive capability. So the absorptive capability can be enhanced from four aspects including knowledge recognition ability, evaluation ability, digestion ability and application ability in order to improve the level of brand marketing strategy. It is necessary to strengthen knowledge recognition ability of analyzing market information and unique resources by improving the efficiency of information and knowledge utilization. Better evaluation ability is required for information distinguishing and digestion ability is required for brand strategy setting by fully making use of acquired information and knowledge. Simultaneously, knowledge application ability helps agribusiness to achieve brand strategy innovation and realize the value of achieved information and knowledge.

Acknowledgments This study was supported by the Natural Science Foundation of Zhejiang province "research on organizational innovation and Performance improvement of private capital's involving in agricultural industrialization in Zhejiang Province" (No.: Y6090628) and Surface project of China Post-doctoral Science Foundation "theory and empirical research on private capital's involving in agricultural industrialization" (No.: 20100471731).

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Chapter 35
Competitive Forces, IT Strategy and Business Strategy: An Empirical Study on Japanese SMEs

Michiko Miyamoto

Abstract Michael Porter's classic framework, "Five Forces" presents the state of competition in an industry depends on five basic forces, such as threat of new entrants, bargaining power of suppliers, bargaining power of customers, threat of substitute products or services, and the industry jockeying for position among current competitors (Porter in How competitive forces shape strategy. Strategic Planning, 2000) [23]. In this paper, a relationship between each of five forces and IT strategy, and a relationship between those and business strategy are examined among Japanese SMEs. Empirical findings in this research present threat of new entrants and bargaining power of customers are positively related to IT strategy as well as business strategy of the firms, while other forces are negatively related to those strategies.

Keywords Competitive advantage · Five forces · IT strategy · Business strategy

35.1 Introduction

It is critical for organizations to learn how to gain competitive advantage. Several studies have analyzed how IT affects competitive advantage. Some studies summarize that the use of Information Technology can give the organization a competitive advantage over its rivals [6, 9, 19, 25]. Others have concluded that IT improves competitive advantage when acting together with certain complementary elements, such as CEO commitment to IT, low conflict levels, the existence of open communications, organizational flexibility and IT planning integration with the overall business plan (e.g. [5, 26]).

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_35,

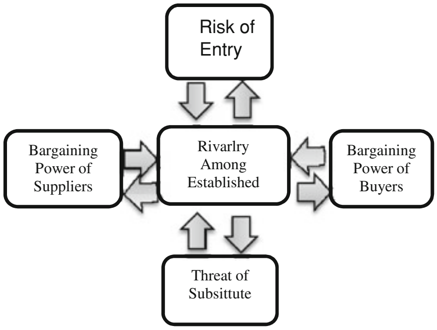

Fig. 35.1 Porter's five forces model

Michael Porter's classic Five Forces Model is known as a useful framework to assist in assessing the competition in an industry and determining the relative attractiveness of that industry [3]. Porter identifies five basic competitive forces seen as threats to the firm profits: (1) Rivalry of competitors within its industry, (2) threat of new entrants into an industry and its markets, (3) threat posed by substitute products which might capture market share, (4) bargaining power of customers; and (5) bargaining power of suppliers. Porter's Five Forces Model [23] helps managers to understand the underlying industry structure, and thus aids in identifying threats and opportunities [28]. This model is depicted in Fig. 35.1, and highlights five forces that shape competition within an industry, and thus determine the overall industry probability and its attractiveness. Porter suggests competitive strategy as taking defensive and offensive actions to deal successfully with the five competitive forces [7].

The development of a strategy aimed at establishing a profitable and sustainable position against these five forces [31]. To survive and succeed, a business must develop and implement strategies to effectively counter the above five competitive forces. O'Brien and Marakas [22] describe that organizations can follow one of five basic competitive strategies, i.e., cost leadership, differentiation, innovation, growth, and alliance, which are based on Porter's three generic strategies of broad cost leadership, broad differentiation, and focused strategy. Porter's "five forces" model to identify strategic business opportunities for use of competitive information systems: (1) Change the basis of competition, (2) raise entry barriers, (3) increase switching costs, (4) change the balance of power, (5) develop new products [32]. Porter and Millar [25] argue that information technology can alter each of the five competitive forces and industry attractiveness as well, and information technology creates value by supporting differentiation strategies. Information systems could be a critical enabler of these five competitive strategies, in the area of cost leadership, differentiation, innovation, growth, and strategic alliance [22]. On top of these five basic strategies, companies can also adopt other competitive strategies facilitated by information systems to shape their competitive advantage.

In this paper, a relationship between each of five forces and IT strategy, and a relationship between those and business strategy are examined among Japanese SMEs.

The paper has four sections excluding the current introduction. In the Sect. 35.2 I define the theoretical background and the hypotheses. The Sect. 35.3 includes the method used to test the hypotheses. Finally, in Sects. 35.4 and 35.5 we detail results and final conclusions.

35.2 Research Background

Many studies in Information systems (ISs) have reported findings about the relationship between IT and firm performance [18]. Liang et al. [18] reviewed 50 published studies to investigate whether IT can enhance firm performance between 1990 and 2009, and found that technological resources can significantly improve organizational capabilities. While some case studies suggested a direct relationship between IT and firm performance [12, 29], other research has frequently been comprehensive [15, 26]. Kettinger et al. [15] list 60 case examples of these strategic information systems, ranging across several industries. They found that less competitive industries are more stable and subsequently leveraged with IT. Porter and Millar [25] provide a number of examples of how IT can change industry structure and may be used throughout the value chain to lower cost, enhance differentiation or spawn new businesses. On the contrary, some research suggests that IT does not have any significant impact [11], or failed to establish a link between IT and company's performance [16, 30].

The development and application of measures to evaluate strategic IT are not adequately represented in current IS research, which heavily weighs toward case studies, anecdotes, and conceptual frameworks, with insufficient empirical work and minimal synthesis of findings [26].

Bharadwaj [5] notes that firms can and do differentiate themselves on the basis of their IT resources, i.e., IT infrastructure, its human IT skills, and its ability to leverage IT for intangible benefits serve as firm-specific resources, which in combination create a firm-wide IT capability.

O'Brien and Marakas [22] mention about several key strategies that can be implemented with information technology which include locking in customers or suppliers, building switching costs, raising barriers to entry, and leveraging investment in information technology. Investments in information technology can allow a business to lock in customers and suppliers (and lock out competitors) by building valuable new relationships with them. A major emphasis in strategic information systems has been to find ways to create switching costs in the relationships between a firm and its customers or suppliers. By making investments in information technology to improve its operations or promote innovation, a firm could also raise barriers to entry that would discourage or delay other companies from entering a market. Typically, these barriers increase the amount of investment or the complexity of the technology required to compete in an industry or a market segment. By making investments in information technology to improve its operations or promote innovation, a firm could also raise barriers to entry that would discourage or delay other companies

Table 35.1 A summary of how information technology can be used to implement the five basic competitive strategies

Basic strategies in the business use of information
Lower costs
• Use IT to substantially reduce the cost of business processes
• Use IT to lower the costs of customers or suppliers
Differentiate
• Develop new IT features to differentiate products and services
• Use IT features to reduce the differentiation advantages of competitors
• Use IT features to focus products and services at selected market niches
Innovate
• Create new products and services that include IT components
• Develop unique new markets or market niches with the help of IT
• Make radical changes to business processes with IT that dramatically cut costs; improve quality, efficiency, or customer service; or shorten time to market
Promote growth
• Use IT to manage regional and global business expansion
• Use IT to diversify and integrate into other products and services
Develop alliances
• Use IT to create virtual organizations of business partners
• Develop inter-enterprise information systems linked by the Internet and extranets that support strategic business relationships with customers, suppliers, subcontractors, and others

from entering a market. Typically, these barriers increase the amount of investment or the complexity of the technology required to compete in an industry or a market segment. Then, armed with this strategic technology platform, the firm can leverage investment in IT by developing new products and services that would not be possible without a strong IT capability.

Table 35.1 is a summary of how information technology can be used to implement the five basic competitive strategies suggested by O'Brien and Marakas [22].

Information and IT increasingly penetrate businesses' products and processes [25], thus becoming not only an isolated, but a corporate wide, ubiquitous source for competitive advantage. Ignoring Strategic Information Planning does not only result in lost strategic opportunities but might also lead to duplicated efforts, incompatible systems and wasted resources [17, 33].

35.3 Research Model and Hypotheses

In this paper, I adopt Porter's five forces model and their relationships with IT strategy and business strategy as a framework for analyzing how Japanese SMEs view their competitive threats (see Fig. 35.2).

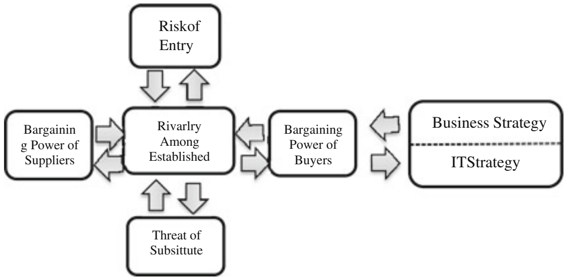

Fig. 35.2 A research model

I had formed ten hypotheses based on this framework as follows.

Hypothesis 1 There is a significant, positive relationship between IT strategy and risk of entry.

Hypothesis 2 There is a significant, positive relationship between IT strategy and bargaining power of suppliers.

Hypothesis 3 There is a significant, positive relationship between IT strategy and rivalry among established firms.

Hypothesis 4 There is a significant, positive relationship between IT strategy and bargaining power of buyers.

Hypothesis 5 There is a significant, positive relationship between IT strategy and threat of substitutes.

Hypothesis 6 There is a significant, positive relationship between business strategy and risk of entry.

Hypothesis 7 There is a significant, positive relationship between business strategy and bargaining power of suppliers.

Hypothesis 8 There is a significant, positive relationship between business strategy and rivalry among established firms.

Hypothesis 9 There is a significant, positive relationship between business strategy and bargaining power of buyers.

Hypothesis 10 There is a significant, positive relationship between business strategy and threat of substitutes.

35.4 Data

Data were collected in the northern part of Japan, in mid-November in 2011 to late December in 2011. A sample of the survey was randomly selected from several databases of those local businesses. 854 companies were selected from these directories. 20 companies had to be withdrawn from the sample since they had no longer existed. The survey was sent to 834 companies of all sizes from various industries, and amassed 354 valid responses (a response rate is 42.4 %). The questionnaire was sent by mail to the information system division, as well as the corporate planning division of the firms. Most of the questionnaires are asked by 5 point scale.

A list of variables is shown in Table 35.2.

Table 35.2 A list of variables

Rivalry of competitors within its industry	Competing 1	(a) There is competitive pressure (price, quality, etc.) from other companies within the same industry
	Competing 2	(b) Products and/or services differentiation from competitors
	Competing 3	(c) Number of other companies that are doing business similar to yours
Threat of new entrants	New1	(a) Large-scale capital investment needed to do business on an ongoing basis
	New 2	(b) Branding of products and services provided
	New 3	(c) Government regulations to industry your company belongs (e.g. new entrants limited company, manufacturing regulations)
Threat posed by substitute products	Substitute 1	(a) Pressures on companies from other industries (price,quality, etc.)
	Substitute 2	(b) Awareness of products and services of other industries with features and performance the same as the products and services your company provided
	Substitute 3	(c) Price-performance ratio of the products and services of other industries with features and performance the same as the products and services your company provided
Bargaining power of customers	Customer 1	(a) Aggressiveness of the customer to be compared to the products and services of other companies for price and performance
	Customer 2	(b) Degree and demand from your customers on price, quality, delivery time, etc.
	Customer 3	(c) Degree of other companies provide products and services that your company provides
Bargaining power of suppliers	Supplier 1	(a) Changing vendor that is currently trading to another one
	Supplier 2	(b) The importance of suppliers that are currently trading in order to enhance the competitiveness
	Supplier 3	(c) Any approach and desire from the vendor to increase in trading volume and price
IT strategy	Top 1	(a) Involvement of IT personnel to process business strategy
	Top 2	(b) Involvement of senior management to IT strategy formulation process
	Top 3	(c) Involvement of senior management for business transformation projects involving IT
	Top 4	(d) Aggressiveness of management for communication with IT personnel
Business strategy	Top 5	(a) Senior management's IT strategy is known to every employee
	Top 6	(b) Management suggests and supports utilization of IT in business
	Top 7	(c) Senior management supports and encourages the use of IT in-house

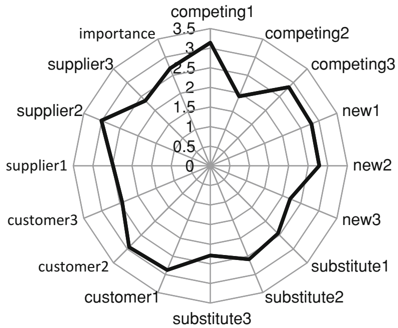

Fig. 35.3 A radar chart of five forces for Japanese SMEs

A radar chart for variable means form the survey on Five Forces is shown in Fig. 35.3. A radar chart suggests that "Products and/or services differentiation from competitors" in the Rivalry of competitors within its industry have gotten the lowest score among the variables. On the other hand, "There is competitive pressure on price, quality, etc., from other companies within the same industry" and "Awareness of products and services of other industries with features and performance the same as the products and services your company provided" have shown the higher scores.

The descriptive results imply that those Japanese SMEs feel less competitive threat in products and/or services differentiation from competitors, while they feel competitive pressure on prices and quality of their products, as well as competitive products/services awareness in their markets.

Table 35.3 contains the Pearson correlation coefficient between all pairs of fifteen variables with the two-tailed significance of these coefficients. Most of variables correlate fairly well, except those of supplier power, and statistically significant, and none of the correlation coefficients are particularly large; therefore, multicollinearity is not a problem for these data.

35.5 The Structural Model Analysis

35.5.1 Five Force Model

Testing the efficacy of the structural equation model was conducted by AMOS 20, and the major results of analysis are shown in Figs. 35.4, 35.5 and 35.6. The path diagram highlights the structural relationships. In this diagram, the measured variables are enclosed in boxes, latent variables are circled, and arrows connecting two variables represent relations, and open arrows represent errors. When SEM is used to verify a theoretical model, a greater goodness of fit is required for SEM analysis [10]; the better the fit, the closer the model matrix and the sample matrix. By means of various goodness-of-fit indexes, including the comparative fit index (CFI) [4], the

Table 35.3 Correlations

		Comp. 1	Comp. 2	Comp. 3	New 1	New 2	New 3	Subs. 1	Subs. 2	Subs. 3	Cust. 1	Cust. 2	Cust. 3	Supp. 1	Supp. 2	Supp. 3
Industry rivarly	Comp.1	1	−0.36***	0.33***	0.16***	0.26***	0.02	0.28***	0.20***	0.12**	0.35***	0.40***	0.12**	0.04	0.14**	0.10*
	Comp. 2	−0.36***	1	−0.19***	−0.21***	−0.41***	0.06	−0.20***	−0.21***	−0.09	−0.34***	−0.24***	0.013	0.02	−0.09	0.02
	Comp. 3	0.33***	−0.19***	1	0.19***	0.15***	0.15***	0.15***	0.16***	0.08	0.37***	0.20***	0.16***	−0.09	−0.04	0.02
Threat of new entrants	New 1	0.16***	−0.21***	0.19***	1	0.31***	0.12**	0.24***	0.14**	0.12**	0.18***	0.17***	0.16***	0.07	0.06	0.05
	New 2	0.26***	−0.41***	0.15***	0.31***	1	0.06	0.23***	0.36***	0.18***	0.21***	0.12***	−0.05	0.15***	0.21***	0.10*
	New 3	0.02	0.06	0.15***	0.12**	0.057	1	0.138**	0.15***	0.14**	0.01	0.014	−0.17	0.14**	0.15***	0.14**
Threat of substi-tutes	Subs. 1	0.28***	−0.20***	0.15***	0.24***	0.23***	0.14**	1	0.60***	0.34***	0.20***	0.30***	0.09	0.07	0.16***	0.15***
	Subs. 2	0.20***	−0.21***	0.16***	0.14**	0.36***	0.15***	0.60***	1	0.50***	0.18***	0.16***	0.04	0.06	0.09	0.05
	Subs. 3	0.12**	−0.09	0.08	0.12**	0.18***	0.14**	0.34***	0.50***	1	0.12**	0.14**	0.10*	0.07	0.08	0.08
Buyer power	Cust. 1	0.35***	−0.34***	0.37***	0.18***	0.21***	0.01	0.20***	0.18***	0.12**	1	0.49***	0.20***	0.06	0.13**	0.15***
	Cust. 1	0.40***	−0.24***	0.20***	0.17***	0.12**	0.01	0.30***	0.16***	0.14**	0.49***	1	0.23***	0.05	0.23***	0.14**
	Cust. 1	0.12**	0.01	0.16***	0.16***	−0.05	−0.07	0.09	0.04	0.10*	0.20***	0.23***	1	0.06	−0.06	0.07
Supplier power	Supp. 1	0.04	0.02	−0.09	0.07	0.15***	0.14**	0.07	0.06	0.07	0.06	0.05	0.06	1	0.47***	0.29***
	Supp. 2	0.14**	−0.09	−0.04	0.06	0.21***	0.15***	0.16***	0.09	0.08	0.13**	0.23***	−0.06	0.47***	1	0.36***
	Supp. 3	0.10*	0.02	0.02	0.05	0.10*	0.14**	0.15***	0.05	0.08	0.15***	0.14**	0.07	0.29***	0.36***	1

Note Comp. Competing, *Subs.* Substitute, *Cust.* Customer, *Supp.* Supplier

*, **, *** means it is significant at 10, 5, and 1 % level

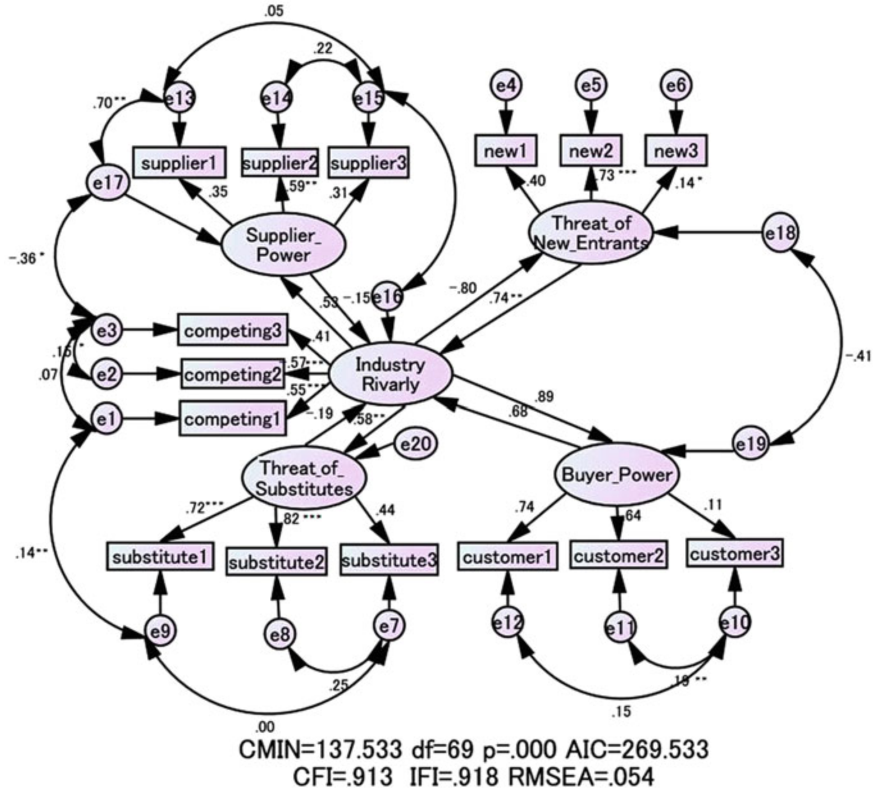

Fig. 35.4 Five forces model for Japanese SMEs

incremental fit index (IFI) [4], and the root mean squared error of approximation (RMSEA) [8] the estimated matrix can be evaluated against the observed sample covariance matrix to determine whether the hypothesized model is an acceptable representation of the data. In general, incremental fit indexes (i.e., CFI, IFI) above 0.90 signify good model fit. RMSEA values lower than 0.08 signify acceptable model fit, with values lower than 0.05 indicative of good model fit [8]. Since all of indexes satisfy the cut-off values, these results are regarded as acceptable.

Testing the efficacy of the structural equation model was conducted by AMOS 20, and the major results of analysis are shown in Figs. 35.4, 35.5 and 35.6. The path diagram highlights the structural relationships. In this diagram, the measured variables are enclosed in boxes, latent variables are circled, and arrows connecting two variables represent relations, and open arrows represent errors. When SEM is used to verify a theoretical model, a greater goodness of fit is required for SEM analysis [10]; the better the fit, the closer the model matrix and the sample matrix. By means of various goodness-of-fit indexes, including the comparative fit index (CFI) [4], the incremental fit index (IFI) [4], and the root mean squared error of approximation

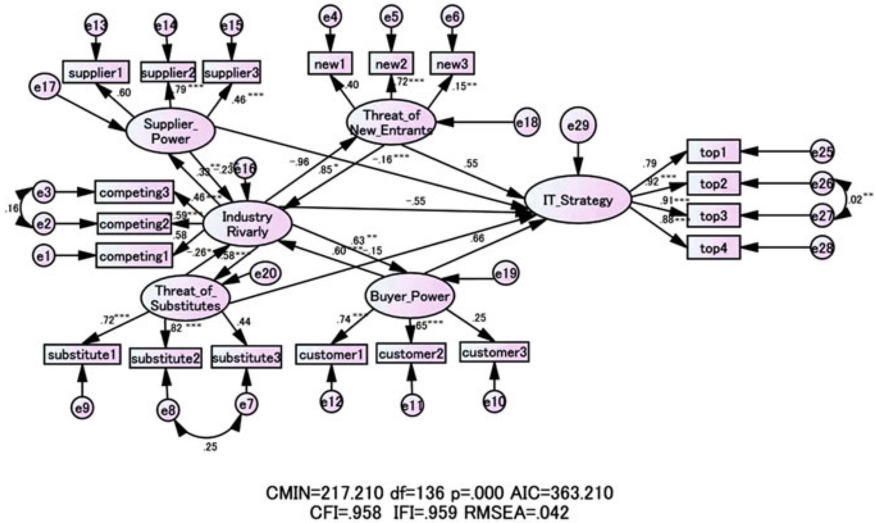

Fig. 35.5 Research model 1

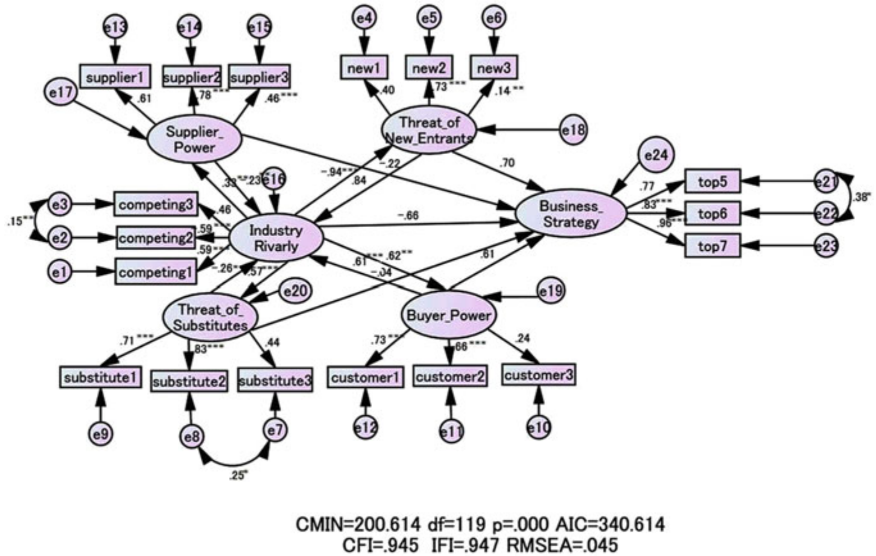

Fig. 35.6 Research model 2

(RMSEA) [8] the estimated matrix can be evaluated against the observed sample covariance matrix to determine whether the hypothesized model is an acceptable representation of the data. In general, incremental fit indexes (i.e., CFI, IFI) above 0.90 signify good model fit. RMSEA values lower than 0.08 signify acceptable model fit, with values lower than 0.05 indicative of good model fit [8]. Since all of indexes satisfy the cut-off values, these results are regarded as acceptable.

A result of five force model for Japanese SMEs (see Fig. 35.4) shows the following eight findings;

1. Threat of new entrants affects industry rivalry positively and significantly.
2. Industry rivalry affects threat of new entrants negatively but not significantly.
3. Buyer power affects industry rivalry positively but not significantly.
4. Industry rivalry affects buyer power positively but not significantly.
5. Threat of substitutes affects industry rivalry negatively but not significantly.
6. Industry rivalry affects threat of substitutes positively and significantly.
7. Supplier power affects industry rivalry negatively but not significantly.
8. Industry rivalry affects supplier power positively but not significantly.

35.5.2 Results of Hypotheses

Research model 1 is testing a relationship between Five Forces and business strategy, while research model 2 is testing those with IT strategy.

Research model 1 is shown in Fig. 35.4; CFI = 0.945, IFI = 0.947, RMSEA = 0.045, while research model 2 is shown in Fig. 35.6; CFI = 0.958, IFI = 0.959, RMSEA = 0.042. Path Coefficient for both structural models suggested that the regression coefficient for all constructs show significance.

The followings are results of hypotheses.

Hypothesis 1 There is a positive but not significant relationship between IT strategy and risk of entry.

Hypothesis 2 There is a negative and significant relationship between IT strategy and bargaining power of suppliers.

Hypothesis 3 There is a negative but not significant relationship between IT strategy and rivalry among established firms.

Hypothesis 4 There is a positive but not significant relationship between IT strategy and bargaining power of buyers.

Hypothesis 5 There is a negative but not significant relationship between IT strategy and threat of substitutes.

Hypothesis 6 There is a positive but not significant relationship between business strategy and risk of entry.

Hypothesis 7 There is a negative but not significant relationship between business strategy and bargaining power of suppliers.

Hypothesis 8 There is a negative but not significant relationship between business strategy and rivalry among established firms.

Hypothesis 9 There is a positive but not significant relationship between business strategy and bargaining power of buyers.

Table 35.4 The path coefficients of research model 1

Construct		Std. weight	Unstd. weight	S.E.	C.R. (t-value)	*P* value
Business strategy	← Threat of new entrants	0.699	1.495	2.424	0.617	0.537
Business strategy	← Supplier power	−0.219	−0.276	0.403	−0.686	0.493
Business strategy	← Industry rivalry	−0.664	−0.9	1.971	−0.456	0.648
Business strategy	← Buyer power	0.61	2.206	3.56	0.62	0.535
Business strategy	← Threat of substitutes	−0.043	−0.081	0.641	−0.126	0.9
Competing 1	← Industry rivalry	0.586	1			
Competing 2	← Industry rivalry	−0.586	−0.828	0.118	−7.04	***
Competing 3	← Industry rivalry	0.458	0.804	0.138	5.838	***
New 1	← Threat of new entrants	0.395	1			
New 2	← Threat of new entrants	0.734	2.147	0.426	5.043	***
New 3	← Threat of new entrants	0.142	0.434	0.219	1.984	0.047
Substitute 3	← Threat of substitutes	0.443	1			
Substitute 1	← Threat of substitutes	0.714	1.786	0.358	4.988	***
Customer 3	← Buyer power	0.245	1			
Customer 2	← Buyer power	0.658	2.58	0.731	3.531	***
Customer 1	← Buyer power	0.735	3.203	0.903	3.545	***
Supplier 1	← Supplier power	0.606	1			
Supplier 2	← Supplier power	0.782	1.09	0.182	6.001	***
Supplier 3	← Supplier power	0.464	0.67	0.113	5.949	***
Substitute 2	← Threat of substitutes	0.829	1.843	0.277	6.663	***
Top 5	← Business Strategy	0.774	1			
Top 6	← Business Strategy	0.825	1.017	0.049	20.96	***
Top 7	← Business Strategy	0.957	1.242	0.16	7.744	***
Industry rivalry	← Threat of new entrants	0.839	1.323	0.361	3.662	***
Industry rivalry	← Threat of substitutes	−0.26	−0.357	0.195	−1.831	0.067
Industry rivalry	← Buyer power	0.608	1.622	0.574	2.828	0.005
Threat of substitutes	← Industry rivalry	0.574	0.418	0.128	3.257	0.001
Supplier power	← Industry rivalry	0.33	0.354	0.175	2.02	0.043
Buyer power	← Industry rivalry	0.624	0.234	0.097	2.4	0.016
Industry rivalry	← Supplier power	−0.232	−0.215	0.101	−2.139	0.032
Threat of new entrants	← Industry rivalry	−0.941	−0.597	1.176	−0.508	0.612

Table 35.5 The path coefficients of research model 2

Construct		Std. weight	Unstd. weight	S.E.	C.R. (t-value)	*P* value
IT strategy	← Threat of new entrants	0.55	1.205	2.424	0.497	0.619
IT strategy	← Supplier power	−0.162	−0.214	0.411	−0.522	0.602
IT strategy	← Industry rivalry	−0.545	−0.774	1.997	−0.388	0.698
IT strategy	← Threat of substitutes	−0.148	−0.289	0.665	−0.435	0.664
IT strategy	← Buyer power	0.655	2.454	3.549	0.692	0.489
Competing 1	← Industry rivalry	0.582	1			
Competing 2	← Industry rivalry	−0.589	−0.837	0.119	−7.042	***
Competing 3	← Industry rivalry	0.46	0.812	0.139	5.843	***
New 1	← Threat of new entrants	0.401	1			
New 2	← Threat of new entrants	0.721	2.075	0.407	5.095	***
New 3	← Threat of new entrants	0.149	0.448	0.217	2.066	0.039
Substitute 3	← Threat of substitutes	0.439	1			
Substitute 1	← Threat of substitutes	0.722	1.822	0.37	4.931	***
Customer 3	← Buyer power	0.246	1			
Customer 2	← Buyer power	0.653	2.545	0.714	3.564	***
Customer 1	← Buyer power	0.74	3.207	0.895	3.584	***
Supplier 1	← Supplier power	0.602	1			
Supplier 2	← Supplier power	0.787	1.105	0.186	5.957	***
Supplier 3	← Supplier power	0.464	0.674	0.113	5.952	***
Substitute 2	← Threat of substitutes	0.821	1.843	0.278	6.627	***
Top 1	← IT strategy	0.787	1			
Top 2	← IT strategy	0.916	1.14	0.062	18.313	***
Top 3	← IT strategy	0.907	1.09	0.06	18.075	***
Top 4	← IT strategy	0.881	1.027	0.055	18.566	***
Industry rivalry	← Threat of new entrants	0.847	1.307	0.356	3.665	***
Industry rivalry	← Threat of substitutes	−0.264	−0.363	0.199	−1.823	0.068
Industry rivalry	← Buyer power	0.604	1.593	0.564	2.826	0.005
Threat of substitutes	← Industry rivalry	0.577	0.419	0.13	3.221	0.001
Supplier power	← Industry rivalry	0.328	0.352	0.178	1.983	0.047
Buyer power	← Industry rivalry	0.626	0.237	0.098	2.411	0.016
Industry rivalry	← Supplier power	−0.234	−0.218	0.102	−2.138	0.033
Threat of new entrants	← Industry rivalry	−0.964	−0.625	1.255	−0.498	0.619

Note: *, **, *** means it is significant at 10, 5, and 1 % level

Hypothesis 10 There is a negative but not significant relationship between business strategy and threat of substitutes. Tables 35.4 and 35.5 summarize the results of these tests for research model 1 and research model 2.

35.6 Summary of Research Results and Future Study

Based on Porter's Five Forces model, I conducted the SEM on the survey data from 345 SMEs located in the northern part of Japan. Analysis is conducted within each of five forces, defined by Porter, including Rivalry among established firms, Risk of entry, Threat of substitute, Bargaining power of suppliers, and Bargaining power of buyers. Among variables in Five Forces, threat of new entrants affects industry rivalry positively and significantly, and industry rivalry affects threat of substitutes positively and significantly.

The relationships between Five Forces and business strategy, and those with IT strategy are not statistically significant; however, threat of new entrant and buyer power are positively related to IT strategy as well as business strategy. Rest of forces are negatively affect IT strategy and business strategy. Porter [24] has introduced additional four competitive forces, such as savvy customers, powerful suppliers, aspiring entrants, and substitute offerings, can hurt companies' prospective profits. I would like to further investigate competitive forces and their relationships with IT strategy and business strategy.

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Part III
Manufacturing

Chapter 36
Identifying Innovation Patterns: Some Insights on Portuguese Manufacturing Companies

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Abstract Innovation is a complex phenomenon including technical and non-technical organizational aspects. The literature refers to technical innovations as those that affect the organizational technical system, while non-technical innovations can be understood as organizational innovations, comprising changes in the structure and processes derived from the implementation of new managerial practices and working principles such as teamwork in production, supply chain management and quality management systems. There are many studies on innovation which show that increased R&D activities lead to innovative products, and are the source of competitive advantage. The importance of organizational innovation has been proved in the literature however there has been little research on the methodological and monitoring approach in this field. Based on previous studies developed in Europe and data collected from the European Manufacturing Survey (EMS), this paper aims to analyze: (1) to which extent technological and organizational innovation concepts are diffused in the Portuguese manufacturing companies; (2) how the use of technological innovation concepts are interrelated to the use of organizational innovation concepts.

Keywords European manufacturing survey · Organizational innovation · Technical innovation · Portuguese manufacturing companies

36.1 Introduction

In a globalized world, innovation has become a cornerstone of sustained economic growth and prosperity and is currently one of the principal topics of debate in the management literature. We often think of innovation in terms of breakthrough inventions however it can also be linked to organizational changes and technology diffusion.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_36,

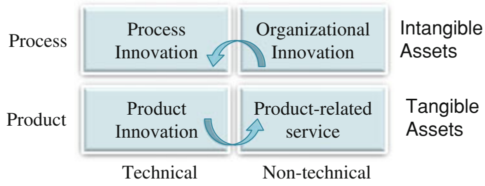
In the literature, competitive advantages are predominantly linked to the research and development (R&D) associated with creating new products, but the competitiveness is also dependent on technical improvements and non-technical organizational aspects that aim to modernize manufacturing processes. Several studies [3, 6, 15, 17] conclude that the ability to modernize technical and non-technical manufacturing processes is crucial to obtain a superior business performance. Technical innovation is usually seen as encompassing product and process innovation, while non-technical innovation can be related to organizational and product innovations. The literature [10–12] shows that the combination of technical and non-technical innovation has a positive impact in innovation performance. Over the last decade we have seen some important shifts in the competitive priorities and the manufacturing action programs of the average European manufacturer. Europe's weakness to compete on price is posing a huge challenge as European companies increasingly confront with new competitors specifically from the Asia Pacific region, whose competitive driver is often based on price. As a response to such challenge European manufacturers are making significant improvements in areas where interface management is important, be it with R&D (in the case of new product development), managerial practices or with product-related services. Based on data from the European Manufacturing Survey (EMS) 2012 and previous studies in other countries [7, 10, 12], this paper aims to identify some innovation patterns in Portuguese manufacturing companies. Data collected from 62 companies participating in the EMS 2012 were used to analyze: (1) to which extent technical and organizational innovation concepts are diffused in the Portuguese manufacturing companies; and (2) how the use of technical innovation concept is interrelated to the use of organizational innovation concept. Case study findings indicate that Portuguese manufacturing companies are more organizational innovation oriented where quality and price are quoted as the most important competitive factors, whilst service offerings and service sales attain far less rank.

Apart from this introductory section, the paper is structured as follows: Sect. 36.2 develops the theoretical framework on technical and non-technical innovation in processes and products; Sect. 36.3 presents the methodology and database and the characterization of sample study; Sect. 36.4 focuses on the central questions driving this study and the findings are discussed. Section 36.5 highlights the main aspects of innovation concepts in Portuguese manufacturing companies and presents the limitations of the study.

36.2 Theoretical Framework

Nowadays, it seems insufficient to see innovation only through the lens of new product development and process innovation or traditional R&D. The Oslo Manual defines innovation as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices (e.g., education and training schemes, codifying knowledge, supply chain management, quality management systems), workplace

Fig. 36.1 Holistic approach on innovation



organization (e.g., new methods for distributing responsibilities and decision making among employees) or external relations (e.g., with other companies or public institutions or customers). Researchers on the innovation field [8, 14] consider innovation a complex phenomenon, comprising technical (e.g., new products, new production methods) and non-technical aspects (e.g., new markets, new forms of organization) as well as product innovations (e.g., new products or services) and process innovations (e.g., new production methods or new forms of organization). Based on this typology, and in line with previous studies, we consider a holistic approach on innovation as depicted in Fig. 36.1, [2].

Technical innovations, usually seen as encompassing products and services, are those that occur in the operating component and affect the technical system of an organization. Product innovation is defined as the introduction of goods or services that are new or significantly improved with respect to their specifications or intended uses [9]. Developed through internal or external innovative activities, product innovations increase the quality and variety of goods and may open up opportunities for firms' growth in output through larger quantities and/or prices. Conversely, process innovations lead to improvements in the efficiency of production increasing productivity and the quality of products.

Non-technical innovations can be understood as organizational innovations, a broad theoretical concept that encompasses strategies, structural and behavior dimensions. The literature refers to a vast variety of organizational innovations which differ in terms of their type and focus. For the purpose of our study we considered non-technical innovations those changes with impact in the structure and processes due to the implementation of: (1) New methods of production (e.g., Value Stream Mapping (VSM), Total Productive Maintenance (TPM), Total Quality Management (TQM), or KANBAN); (2) New methods of work organization (e.g., teamwork in manufacturing, task integration, continuous improvement process, or standardized work instruction); (3) Application of standards and audits (e.g., visual management, six sigma or ISO certifications), and (4) Practices and processes focused on human resource management (e.g., sessions for idea generation, talent development programs, or employee training). Recent changes in business environment derived from the globalization of markets, shifts in consumer demand and increasing competitiveness from emergent economies are shifting the focus of European manufacturers from pure manufacturing to a combination of manufacturing and services. The literature stresses that customized technological products increase company's returns as value is added through services offered along the entire supply chain, and can also generate new market niches. However some works [7] show that the vast majority of European companies offer services, despite the turnover generated by services be low, and the adopted service strategies do not seem fully developed.

Recent studies on innovation [5, 13] emphasize the iterative character of innovation processes where non-technical dimensions play a significant role in maintaining and improving competitiveness and growth, and stress that non-technological factors are a requirement for getting the most of company's capacity for technological innovation, both as an enabler and facilitator of an efficient use of technical product and process innovations, and for knowledge development in companies. In the same vein, [2] refers that "companies are inter-dependent in their innovation activities". Organizational innovation is crucial either as a necessary adaptation to the introduction of new technologies, or as a precondition for successful product or technical process innovations. Surprisingly, little work has been developed to address how the use of technical innovation concept is interrelated to the use of organizational innovation concept. Following previous studies and based on data collected from the EMS 2012, this work analyzes the diffusion of technical and non-technical innovation concepts among Portuguese manufacturing companies.

36.3 Methodology and Database

Present data are derived from the European Manufacturing Survey 2012 (EMS 2012), for the first time compiled for manufacturing companies in Portugal [4]. It was conducted by Research Unit in Mechanical and Industrial Engineering (UNIDEMI), Faculty of Sciences and Technology, Universidade Nova de Lisboa. The survey covers a range of manufacturing industries, namely, machinery, metal industries, food, textile, chemicals, automotive, with 20 or more employees. Data collected from the EMS 2012 are used to analyze the implementation of innovative manufacturing technologies and organizational concepts, and the product-related services with impact in the modernization of Portuguese manufacturing companies. The survey was delivered to companies via the Internet. The advantages associated to this method are low cost, expanded geographic coverage, more time to respondents to think and also fast data collection. One of the major disadvantages is low response rate. The current research defines as unit of analysis the EMS companies' responses and the unit of response the single company/manufacturing site.

The survey was sent to 2,370 Portuguese companies with 20 or more employees and 62 valid responses (N) were obtained (2.6 % response rate was achieved).

Approximately 60 % of respondents to the survey have the position of General Director or Production Manager.

The survey focused on six competitive factors, as shown in Tables 36.1 and 36.2. Respondents were asked to rate the importance of each competitive factor with a six-point scale from 1 (most important) to 6 (least important). Statistical analysis reveals that "product quality" is the most important competitive factor followed by "product price", whilst service offerings and innovative products attain far less rank.

Table 36.1 Relative importance of competitive factors

Competitive factors	Product quality	Product price	Product customization	Short time delivery	Product related service	Product innovation
Mean	1.94	3.03	3.50	3.94	4.10	4.50
Ranking	1	2	3	4	5	6

Table 36.2 Classes, sub-classes and variables of organizational and technological innovation concepts

Class	Sub-class	Variables
Organizational	Organization of production	Methods of value stream mapping/Design; Customer/product oriented shop floor segmentation; Production controlling by pull principles; TPM; TQM
	Organization of work	Method of 5S; Standardized and detailed work instruction; Methods for continuous improvement process; Teamwork in manufacturing and assembly
	Standards and audits	Visual management; ISO 9000 et seq. certification; ISO 14031; ISO 50001; Methods of investment evaluation
	Human resource management	Formalized sessions for idea generation; Maintain elderly employees or their knowledge; Working time dedicated for creativity/innovation; Talent development program
Technological	Robotics and automation	Industrial robots/handling systems; Automated warehouse management systems; Technologies for safe human–machine cooperation; Intuitive, multi-modal programming methods
	Processing and production technologies	Processing techniques for alloy construction materials; Processing techniques for composite materials; Manufacturing technologies for micromechanical components; Nanotechnological production processes
	Digital factory/IT cross-linkage	Digital exchange of operation scheduling with data suppliers; Virtual reality and/or simulation in production reconfiguration; Virtual reality and/or simulation in product design; Product lifecycle management; IT systems for storage and management of ideas
	Energy and resources efficiency	Dry processing/minimum lubrication; Control system for shut down of machines; Recuperation of kinetic and process energy; Combined cold, heat and power

36.4 Central Questions to be Answered

This section provides the results obtained from the statistical analysis performed by SPSS Statistics Software to some EMS responses. Due to complexity of some topics, it was necessary to carry out several questions about the same topic, which need an appropriate statistical analysis. Some data was coding in order to transform text responses to numeric form.

The study of the organizational innovation concepts used in the manufacturing site is based on the responses obtained from 22 questions which were transformed into 22 dummy variables—the value 1 means that the organizational concept is used and 0 otherwise. The 22 organizational variables are segmented in four classes, (1) Organization of production, (2) Organization of work, (3) Standards and audits, and (4) Human Resource Management, as described in Table 36.2. Technological innovation concepts, based on 17 dummy variables, are also segmented in four classes, (1) Robotics and automation, (2) Processing and production technologies, (3) Digital factory/IT cross-linkage, and (4) Energy and resources efficiency (Table 36.2).

1. Question 1—Results and Analysis

Question 1 is: "To which extent organizational and technological innovation concepts are diffused in the Portuguese manufacturing companies?"

(1) Organizational innovation concepts

The applying of the organizational innovation concepts is very heterogeneous regarding sub-classes. The "teamwork in production" concept has the highest applying level (71 %), and there are seven concepts with over 50 %. All concepts included in the "organization of work" sub-class have a high applying level (between 45 and 71 %). Instead, the concepts of "standards and audits" sub-class are the ones less diffused (on average 31 %), as depicted in Fig. 36.2. In Fig. 36.2, O_P1: Methods of Value Stream Mapping/Design; O_P2: Customer/Product oriented shop floor segmentation; O_P3: Production controlling by pull principles; O_P5: TPM; O_P6: TQM; O_W1: Method of 5S; O_W2: Standardized and detailed work instruction; O_W3: Task integration; O_W4: Methods for continuous improvement process; O_W5: Teamwork in manufacturing and assembly; S_A1: Visual Management; S_A2: ISO 9000 et seq. certification; S_A3: Six Sigma; S_A4: ISO 14031; S_A5: ISO 50001; S_A6: Methods of investment evaluation; HRM1: Formalized sessions for idea generation; HRM2: Maintain elderly employees or their knowledge; HRM3: Working time dedicated for creativity/innovation; HRM4: Talent development program; HRM5: Employee training for creativity and innovation.

Regarding the use planned until 2015, on average, companies reported expecting to use 21 % more of the organizational innovation concepts, with values between 8.5 % ("production controlling by pull principles") and 37.9 % ("total productive maintenance"). So, in 2015 the level of application of the organizational innovation concepts should be around 61 %, having eight organizational concepts values above 80 %. It should be noted that there is at least one company that applies all the concepts of all sub-classes.

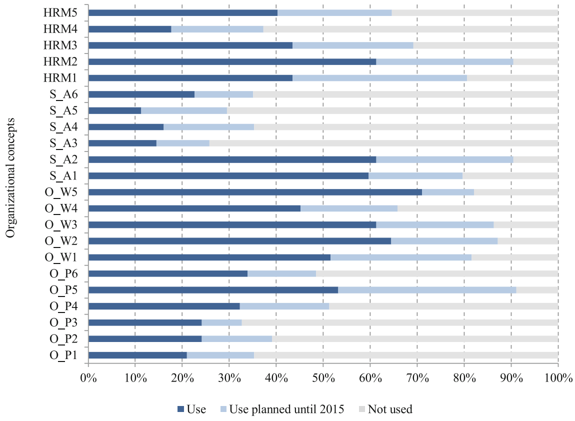


Fig. 36.2 Organizational innovation concepts

Table 36.3 Level of application of organizational innovation sub-class concepts

Organizational sub-class concepts	Number of concepts	Mean	Std. deviation	Maximum
Organization of work	5	0.587	0.338	1.000
Human resource management	5	0.413	0.313	1.000
Organization of production	6	0.315	0.327	1.000
Standards and audits	5	0.309	0.265	1.000

Table 36.4 Coefficient correlation of Pearson of organizational innovation concepts sub-classes

Organizational sub-class	Organization of work	Standards and audits	Human resource management
Organization of production	0.627 (<0.001)	0.659 (<0.001)	0.584 (<0.001)
Organization of work		0.541 (<0.001)	0.584 (<0.001)
Standards and audits			0.492 (<0.001)

The descriptive information shows the means and standard deviations for the four organizational sub-classes (Table 36.3), as well as all possible bivariate correlations and their p-values (Table 36.4). We note that all correlations are positive and are significant at a significance level of 0.001.

Answering to question 1, the organizational innovation concepts are more diffused than the technological ones in the Portuguese manufacturing companies. Also, the level of application of the technological innovation concepts is more heterogeneous than the organizational concepts which may be due to the type of industry of the companies and to the economic crisis facing the country.

(2) Technological innovation concepts

The concepts "industrial robots/handling systems", "virtual reality and/or simulation in product design" and "control system for shut down of machines" are the most diffused in the Portuguese manufacturing companies (33–40 %), but each one belongs to a different technological sub-class. The "processing and production

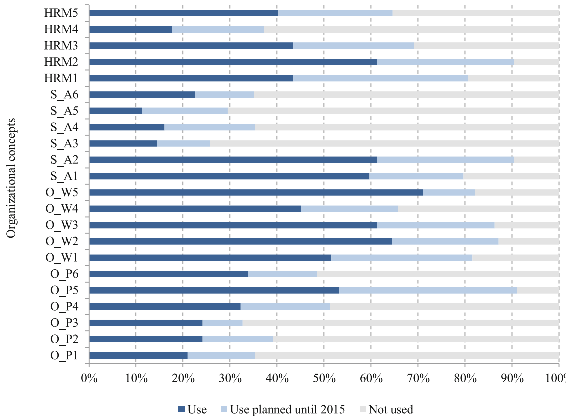


Fig. 36.3 Technological innovation concepts

technologies" sub-class is the least diffused (on average, only 5.2 % of the manufacturing sites applied it). The "processing techniques for alloy construction materials" concept is the most used in this sub-class, though it is only in the 12th place (in 17 possible) regarding the applying of each concept by companies, Fig. 36.2. In Fig. 36.2, R_A1: Industrial robots/handling systems; R_A2: Automated Warehouse Management Systems; R_A3: Technologies for safe human–machine cooperation; R_A4: Intuitive, multi-modal programming methods; P_PT1: Processing techniques for alloy construction materials; P_PT2: Processing techniques for composite materials; P_PT3: Manufacturing technologies for micromechanical components; P_PT4: Nanotechnological production processes; DF_IT1: Digital exchange of operation scheduling with data suppliers; DF_IT2: Virtual reality and/or simulation in production reconfiguration; DF_IT3: Virtual reality and/or simulation in product design; DF_IT4: Product Lifecycle Management; DF_IT5: IT systems for storage and management of ideas; E_RE1: Dry processing/minimum lubrication; E_RE2: Control system for shut down of machines; E_RE3: Recuperation of kinetic and process energy; E_RE4: Combined cold, heat and power.

Regarding the planned use until 2015, on average, companies must use more 11 % of each of the technological innovation concepts, with values between 3.7 % ("Processing techniques for alloy construction materials") and 28.3 % ("IT systems for storage and management of ideas"). Anyway, by 2015, the level of application of any technological innovation concept should not exceed 54 %. From the respondents 21 % did not apply any of the technological innovation concepts and none apply all concepts (Fig. 36.3).

Descriptive information shows the means and standard deviations for all of the four technological sub-classes (Table 36.5), as well as all possible bivariate correlations and their p-values (Table 36.6). All correlations are positive and most are significant at a significance level of 0.05. It is noted that only two of the sub-classes have at least one company that applies concepts of these sub-classes and that in the maximum 50 % of the concepts of the "processing and production technologies" sub-class are applied.

Table 36.5 Level of application of technological innovation concepts sub-classes

Technological sub-class concepts	Number of concepts	Mean	Std. deviation	Maximum
Digital factory/IT cross-linkage	5	0.265	0.292	1.000
Robotics and automation	4	0.210	0.287	1.000
Energy and resource efficiency	4	0.185	0.207	0.750
Processing and production technologies	4	0.052	0.112	0.500

Table 36.6 Pearson correlation coefficient of technological innovation concepts sub-classes

Technological sub-class	Processing production technologies	Digital factory/ IT cross-linkage	Energy resource efficiency
Robotics automation	0.226 (0.077)	0.571 (<0.001)	0.386 (0.002)
Processing production technologies		0.321 (0.011)	0.236 (0.065)
Digital factory/IT cross-linkage			0.464 (<0.001)

2. Question 2 Results and Analysis

Question 2 is "How the use of technological innovation concept is interrelated to the use of organizational innovation concept?"

To reduce the number of variables defined by the responses to the questions "Which of the following technologies are currently used in your factory?" and "Which of the following organizational concepts are currently used in your factory?" (17 and 22 variables, respectively) factor analysis is used.

(1) Organizational innovation concepts

The levels of application of the four sub-classes (Table 36.4) of each company are the variables used as the basis for the Principal Component Analysis (PCA). Barlett's test of sphericity is significant (=98.496; $p < 0.001$), thus the hypothesis that the inter-correlation matrix involving these four variables is an identity matrix is rejected. Thus from the perspective of Bartlett's test, factor analysis is feasible. As Bartlett's test is almost always significant, a more discriminating index of factor analyzability is the Kaiser-Meyer-Olkin (=0.804), which is meritorious and supports factor analysis [16].

Through the application of the PCA and according with Kaiser criterion one factor (Factor_Org) is extracted (with an Eigenvalue = 2.747), which accounts for 68.7 % of the variance (Table 36.7).

The factor scores (Table 36.8) permits to have new variables that could be substituted for the original variables in other statistics techniques in order to have the applying level of organizational innovation concepts.

(2) Technological innovation concepts

From the perspective of Bartlett's test factor analysis is feasible (Barlett's test of sphericity = 46.226; $p < 0.001$), like to in organizational innovation concepts. For this data set, Kaiser-Meyer-Olkin (=0.705) is middling, which supports factor analysis. Applying the PCA one factor (Factor_Tech) is extracted, which accounts for 53 % of the variance. Factor scores (Table 36.9) permits to

Table 36.7 Component score coefficient matrix

Organizational class	Component
Organization of production (OP)	0.317
Organization of work (OW)	0.303
Standards and audits (SA)	0.295
Human resource management (HRM)	0.291

Table 36.8 Component score coefficient matrix

Technological class	Component
Robotics and automation (RA)	0.365
Processing and production technologies (PPT)	0.255
Digital factory/IT cross-linkage (DF)	0.395
Energy and resource efficiency (ERE)	0.339

Table 36.9 Regression output summary

R^2	Adjusted R^2	Std. error of the estimate	F test	df2	df2	Sig.F	Durbin-Watson test
0.420	0.410	0.768	43.402	1	60	<0.001	1.997

Table 36.10 Linear regression coefficient and statistics

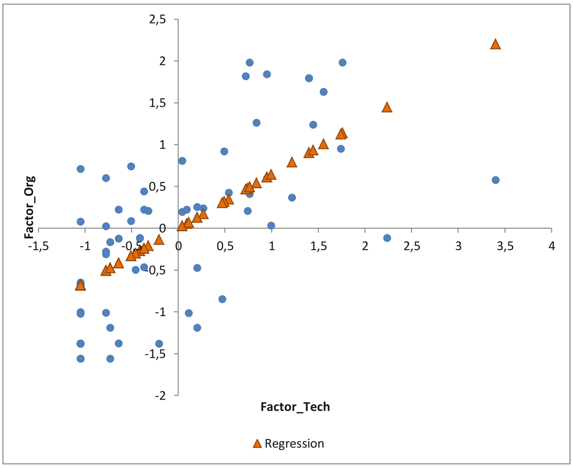
	B coef	Std. error	t test	p-value
Factor_Tech	0.648	0.098	6.588	<0.001

have new variables in order to have the applying level of technological innovation concepts.

The two factors scores, saved as variables, will be used in subsequent analyses in order to identify how technological innovation concept is interrelated to the use of organizational innovation concept. With this objective a regression analysis was applied to Factor_Tech and Factor_Org, where Factor_Tech is the dependent variable and Factor_Org is the independent variable. Pearson correlation coefficient between the two factors (=0.648) permits say that there is a positive and significant correlation between the two variables at a significance level <0.001. Assessing the overall model fit (Table 36.9), the results showed that the regression is statistically significant ($p\text{-}value < 0.001$ and Adjusted $R^2 = 0.410$). Also, the output of the regression analysis shows that the overall model is significant as the *p-value* of the F-test <0.001. The R^2 is 0.420, meaning that approximately 42 % of the variability of Factor_Org is explained by the variability of Factor_Tech. The Durbin-Watson statistic shows that residuals were independent and normally distributed.

Table 36.10 reports the linear regression coefficient, and respective standard error, t test and *p-value*.

Fig. 36.4 Plot of fitted model



The results show that technological and organizational innovation concepts are positive and significantly linearly associated (Fig. 36.4).

Considering the adjusted R^2 value of the regression model, we believe that the unexplained variance of the dependent variable (that had as a result a quite low R^2 adjusted value) is coming from the diversity of the type of industries that constitute the sample companies that answered the EMS.

3. Question 3—Results and Analysis

36.5 Conclusions

Based on data collected from the EMS in Portugal, this paper aims to analyze three central questions.

Concerning the diffusion rates of organizational and technological innovation concepts, 22 and 17 variables, respectively, they are distinct among the surveyed companies. Around 5 % of respondents did not apply any organizational innovation concept and 21 % did not apply any technological innovation concepts. No one company applies all concepts (organizational and technological), and around 3 % did not apply any concept (organizational and technological). The organizational innovation concepts are more diffused than the technological innovation concepts and the level of application of the technological innovation concepts is more heterogeneous than the organizational concepts which may be due to the type of industry of the companies and to the economic crisis facing the country.

The 22 organizational innovation concepts were classified in four sub-classes and the 17 technological innovation concepts also were classified and four sub-classes. The Principal Component Analysis was used to reduce the problem dimension (eight sub-classes of innovation concepts) allowing to identifying two factors, one to each innovation concept class (organizational and technological innovation concepts). Through the regression analysis it was verified that technological innovation concepts are positive, linear and significantly related with organizational innovation concepts among the respondent companies. Approximately 42 % of the variability of organizational innovation concepts was explained by the variability of technological innovation concepts.

It seems consensual that in an international competition there is little change that Europe will win on price competition. So we will have to innovate more. We argue that future action programs, centered on people and quality, should provide our manufacturing companies with a solid competitive base for the increased international competition. Improving our ability to innovate will require a balance of people-orientated programs and technology deployment.

This study has some limitations; the EMS response rate is reduced, and has been drawn from only one country (Portugal) which can biased the result analysis.

Acknowledgments The authors would like to thank the Unidade de Investigação e Desenvolvimento em Engenharia Mecânica e Industrial for its support (PEst-OE/EME/UI0667/2011).

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Chapter 37
Integrated System Health Management for Environmental Control and Life Support System in Manned-Spacecraft

Fan Li and Yusheng Wang

Abstract This paper addresses the integrated system health management (ISHM) diagnostics and prognostics for a manned spacecraft's environmental control and life-support system (ECLSS), which ensures the safety of astronauts and guarantees space mission success. For the complex system structure, an integrated diagnostics and prognostics method is presented, which allows for the consideration of continuously monitored signals. In this method, the condition monitoring data are first classified by exploiting the comprehensive evaluation technique, and then the feature data are used to train the corresponding diagnosis models, which themselves represent the different stages of system degradation. Due to the variant behavior of the ECLSS in the space environment, variational approximation-based learning is designed in the diagnostics procedure to estimate the parameter distribution of the trained models rather than the parameters themselves. By exploiting the constructed trained models, the current ECLSS health stage and remaining useful life (RUL) can be identified. A numerical stimulation is provided to demonstrate the performance of the proposed integrated algorithm.

Keywords Integrated system health management · Environmental control and life support system · Diagnostics · Prognostics

37.1 Introduction

Manned space flight allows for the exploration of the universe and is, by its very nature, complicated and innovative [14]. The functions of the earth's natural life support system such as the provision of air, water, and other conditions must be

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_37,

performed by artificial means in manned spacecraft to guarantee that people can live and work in space. To meet this need, the environmental control and life support system (ECLSS) plays an important role in the development of future space shuttles to provide the crew with a comfortable environment in which to live [16]. ECLSS are critical subsystems in manned spacecraft as they are an indispensable safeguard for life in the harsh environmental conditions of space and on lunar and planetary surfaces [8].

Health management, which can guarantee the reliability of the system by evaluating its life-cycle conditions, determining the advent of failure, and mitigating system risks, has been viewed as having the role of an autonomic safeguard, and is also vital to complex systems such as the ECLSS [5, 12]. However, health management for ECLSS is a complex task, due to the complex system structures and the large amount of devices and interfaces in the ECLSS subsystems, both of which may cause complicated failure mechanisms. The complexity of the ECLSS can be attributed to the highly nonlinear behavior of the individual subsystems, the effect of which is further magnified by the number of interacting subsystems, and the fact that these systems have to operate with limited resources in unpredictable environments. In the ISHM for the ECLSS, the health stages for the system environment need to be comprehensively evaluated by exploiting the monitored data from different subsystems. Then, diagnostics are conducted to identify the current health condition and the extent of the degradation, and prognostics are then needed to predict the remaining useful life (RUL) and the associated confidence bounds for the system within the limited resources in space. Hence, an ISHM, with its efficient diagnostic and prognostic capability, has become a very important design requirement as a result of the need to provide the ECLSS in spacecraft with system level health management.

This paper deals with the integrated assessment, diagnostics and prognostics of a designed ISHM framework for an ECLSS. Previous research has discussed the key techniques, including data preprocessing, health assessment, diagnostics and prognostics respectively for ISHM, but the integrated capability in the complex system has not been well implemented which just focused on the conceptual framework design [4]. In this paper, integrated diagnostics and prognostics are presented for the ISHM of an ECLSS, by using data-based learning. In the proposed diagnostic and prognostic method, the diagnostics and prognostics can be performed in two main phases; the learning phase and the exploitation phase. During the learning phase, the monitored data with a known health condition are used in the trained diagnostic models to represent the system's health stages. The trained models are based on a mixture of Gaussian Hidden Markov Model (MoG-HMM), which allows for continuous observations through the taking in of input. By exploiting proposed learning algorithm, the parameter distributions of the MoG-HMM, rather than the fixed parameters, are estimated, which better represents the degradation of the complicated ECLSS in a complex environment. In the exploitation phase, when the monitored feature data are obtained, the current health stages of the ECLSS are determined by exploiting the statistical properties of the trained models. Based on the current diagnostics results, furthermore, the RUL and associated confidence bounds are estimated.

The rest of this paper is organized as follows: Sect. 37.2 first describes the ISHM scheme for the ECLSS, where the key to the ISHM implementation is presented. Then the integrated diagnostics model for ISHM is given in Sect. 37.3. Section 37.4 is dedicated to the proposed diagnostic and prognostic method. Numerical examples are illustrated to demonstrate the performance of the proposed algorithm in Sect. 37.5. Section 37.6 gives some conclusions.

37.2 Problem Statement

In general, the main functional subsystems of the ECLSS used in aeronautic and aerospace applications include a unified form: atmosphere control and supply (ACS), atmosphere revitalization (AR), temperature and humidity control (THC), water recovery and management (WRM), waste management (WM), fire detection and suppression (FDS), and spacesuits [9]. The ACS provides the cabin with sufficient oxygen and nitrogen, adjusting pressure immediately. The objective of the AR is to maintain the trace harmful gases in the crew's cabin within safe bounds. The THC ensures an equal distribution of temperature, humidity and gas around the astronauts. The WRM and WM deal with liquid and solid waste, respectively. The FDS monitors any exceptional smoke and fire situations to trigger a timely alarm. The spacesuit is a relatively independent subsystem which works as an emergency backup for the manned spacecrafts ECLSS. Depending on the duration and distance from earth of a mission, the ECLSS varies greatly in complexity [3, 13]. However, one of the key elements of the ECLSS, the ISHM for ECLSS, can have a direct bearing on crew safety and mission success and must be pursued with a careful and systemic consideration of the monitoring capability, safety margins, maintenance, and sustainment requirements. Therefore, ISHM-based state evaluation, diagnostics and prognostics have become necessary for the ECLSS in providing effective health management under an uncertain environment [6]. A feasible ISHM framework which considers integrated assessment, diagnostics and prognostics is proposed to improve the ECLSS health management at the system level. Figure 37.1 shows the ECLSS ISHM conceptual framework.

As can be seen in Fig. 37.1, data from the functional ECLSS subsystems are first monitored in situ, and then the data are pre-processed to extract feature parameters. For some health state factors it is difficult to give an accurate quantitative description and therefore expert knowledge and historical data are needed. Diagnostics and prognostics are then conducted used the health assessed information. In the ISHM conceptual framework, these processes determine the system's current state of health, diagnose and identify malfunctions, and estimate the advent of failure by providing a distribution of the RUL, and the current level of deviation or degradation [15]. The main purpose for the diagnostics and prognostics is to recognize the system's actual state and estimate the remaining time before failure. Based on that, the decisions for safeguarding and maintenance can be determined.

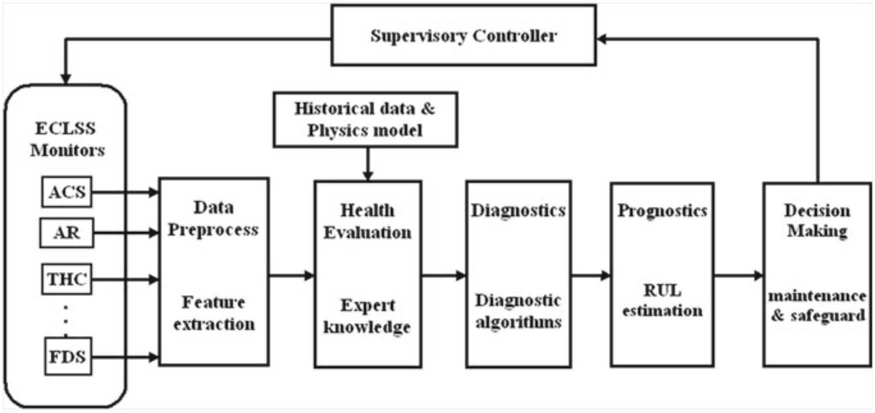

Fig. 37.1 ISHM conceptual framework for ECLSS

37.3 ISHM-Based Diagnostics Model

From the ECLSS ISHM framework, the diagnostics and prognostics are vital, but for an integrated implementation, the feature information needs to be used. For a complex system with limited resources, a degrading of the system, which cannot directly observed, may result from the transition of some different stages. The integrated ECLSS diagnostics and prognostics needs to make full use of the feature data from the monitoring sensors to build the behavioral models of the system states through a learning process.

Consider the characteristics of the whole system, the ECLSS health states are difficult to observe directly, as the only information that can be obtained is the monitored data from the subsystems. Usually, an HMM represents stochastic sequences as Markov chains, where the states are not directly observed, but the output depends on the states which are visible. Thus, let the Markov chains state sequence be $\{s_t\}_{t=1}^{T}$, i.e., $P(s_t|s_{t-1}, \cdots, s_1) = P(s_t|s_{t-1}), \forall t$, and the associated observation sequence be $Y = \{y\}_{t=1}^{T}$, supposed that $s_t \in \{1, 2, \cdots, N\}$, $y_t \in \{1, 2, \cdots, M\}, \forall t$, then the discrete HMM is completely defined by the following parameters:

1. The initial state distribution: $\pi = [\pi_i]$, where $\pi_i = P(s_1 = i), 1 \leq i \leq N$.
2. The state transition probability distribution: $A = [a_{ij}]$, where $a_{ij} = P(s_t = j|s_{t-1} = i), 1 \leq i, j \leq N$.
3. The observation probability distribution: $B = [b_i(k)]$, where $b_i(k) = P(y_t = k|s_t = i), 1 \leq i \leq N, 1 \leq k \leq M$.

It can be seen that the model parameters for the HMM are π, A, B. The discrete HMM model considers the observations as discrete symbols and uses discrete probability densities to model the transition and the observation probabilities. However, the observations from the condition monitoring are typically continuous variant signals in practice [7, 10]. In order to overcome this limitation, the MoG-HMM can be used in which the distribution of the observations are viewed as a combination of a finite number of mixtures, i.e., $b_j(y_t) = \sum_{k=1}^{K} c_{jk} N(y_t; \mu_{jk}, \Sigma_{jk})$. In the Mixed Gaussian observations, let $z_t = k$ represent the k density at t, then the corresponding weight is $c_{jk} = P(z_t = k|s_t = j)$. By assuming a mixture of Gaussian rather than using just a Gaussian distribution, the observations can be identified with differing covariance structures. The complete parameter set of the MoG-HMM can be given by the compact notation $\theta = (\pi, A, B, C, \mu, \Sigma)$, where, $(\mu, \Sigma) = (\{\mu_{jk}\}, \{\Sigma_{jk}\})$.

The parameters of the models are important, as they can determine the MoG-HMMs. For the diagnostics learning process, the goal is to recognize the different ECLSS health stages by exploiting the trained models. Different trained models learn from different groups of monitored data, which represent the different health stages of the system. Therefore, the ECLSS diagnostics needs to develop the diagnosis models from the monitored data from varying health conditions, and so it is essential to learn the parameters of the models which represent the characteristics of their corresponding diagnosis model. However, because the ECLSS is under a complex space environment, the fixed parameters cannot represent the degradation when the system under conditions varies greatly, so there should be uncertain parameters with some distribution. In other words, the parameters of the trained model have an unknown distribution:

$$p(\theta) = p(\pi)p(A)p(C)p(\mu)p(\Lambda), \tag{37.1}$$

where $\Lambda = \Sigma^{-1}$, consider the parameters being independent. With the diagnostics model's parameter distribution, the extracted features information from the conditional monitoring histories are transformed into different MoG-HMMs associated to the ECLSS health stages. After that, when the current monitored data is obtained, the identification or exploitation can be conducted by comparing the observations likelihood under different trained models. According to the highest likelihood for the observations, the ECLSS current health stages can be identified.

37.4 Integrated Diagnostics and Prognostics

In order to implement the integrated diagnostics and prognostics for ECLSS in the space environment, the learning phase and exploitation phase need to exploit the parameter distributions of the diagnosis models. In this situation, the only solution is to estimate the distributions of those parameters using the Bayesian approach.

1. Variational Bayesian Method

The classical Bayesian inference is to estimate the conditional probability density of the unknown parameters θ under the condition of given observations Y. It is assumed that the density of observations Y with respect to the parameters θ, i.e., $p(Y|\theta)$, called the conditional likelihood function, can be known. The estimation result of the conditional probability density function $p(Y|\theta)$ with respect to a given observation Y, which is called the posterior distribution of θ, can be yielded as follows by using the Bayesian Theorem.

$$p(\theta|Y) = \frac{p(Y|\theta)p(\theta)}{\int p(Y|\theta)p(\theta)d\theta} . \tag{37.2}$$

Here $p(\theta)$ is the prior distribution of θ. Taking the Bayesian framework, the prior distributions of those parameters are assumed, then the posterior density of the parameters can be obtained by exploiting the observations likelihood.

From the above formula, the difficulty is that the analytical solution to calculate the integral of Eq. (37.2) is generally difficult. Several methods, such as the Monte Carlo method and sampling methods [11], are available but these require significant computational effort. Thus, the variational approximation method is used here to approximate the analytical solution of Eq. (37.1). In the diagnostics models from our learning phase, there are two unknown parameters: the model parameter θ and the hidden variable $\mathbf{x}$. Denoting the true posterior distribution of those parameters as $p(\mathbf{x}, \theta|\mathbf{y})$, and the approximated density as $q(\mathbf{x}, \theta)$, the approximation principle is given as follows.

From the observation log-likelihood $\log p(\mathbf{y})$, it can be expressed by:

$$\log p(\mathbf{y}) = \int \mathbf{dxd}\theta\mathbf{q}(\mathbf{x}, \theta)\log\frac{\mathbf{p}(\mathbf{x}, \mathbf{y}, \theta)}{\mathbf{p}(\mathbf{x},\ \mathbf{theta}|\mathbf{y})} = \mathbf{KL}(\mathbf{q}(\mathbf{x}, \theta)\|\mathbf{p}(\mathbf{x}, \theta|\mathbf{y})) + \mathbf{F}(\mathbf{q}(\mathbf{x}, \theta)), \tag{37.3}$$

where, $F(q(\mathbf{x}, \theta))$ can be written as:

$$F(q(\mathbf{x}, \theta)) = \int \mathbf{dxd}\theta\mathbf{q}(\mathbf{x}, \theta)\log\frac{\mathbf{p}(\mathbf{x}, \mathbf{y}, \theta)}{\mathbf{q}(\mathbf{x}, \theta)}$$

and it is actually the function of $q(\mathbf{x}, \theta)$.

From Eq. (37.3), the Kullback-Leibler (KL) divergence describing the distance between the true posterior density $p(\mathbf{x}, \theta|\mathbf{y})$ and its approximation $q(\mathbf{x}, \theta)$ is nonnegative, and equal to zero if and only if the two densities are the same. Further, the left side of Eq. (37.3) does not depend on the estimated density. This means that minimizing the KL divergence is equivalent to maximizing $F(q(\mathbf{x}, \theta))$ by selecting the function q. Consequently, a distribution $q(\mathbf{x}, \theta)$ maximizing $F(q(\mathbf{x}, \theta))$ can be viewed as the best approximation of the true posterior distribution. Suppose that the model parameters are independent of the hidden variables in the approximation distribution, thus, its density can be written as $q(\mathbf{x}, \theta) = \mathbf{q}(\mathbf{x})\mathbf{q}(\theta)$. Then, the functional $F(q(\mathbf{x}, \theta))$ can be given as:

$$F(q(\mathbf{x}, \theta)) = \int \mathbf{dxd}\theta\mathbf{q}(\mathbf{x})\mathbf{q}(\theta)\log\frac{\mathbf{p}(\mathbf{x}, \mathbf{y}|\theta)}{\mathbf{q}(\mathbf{x})} + \int \mathbf{d}\theta\mathbf{q}(\theta)\log\frac{\mathbf{p}(\theta)}{\mathbf{q}(\theta)}. \tag{37.4}$$

In order to maximize the functional $F(q(\mathbf{x}, \theta))$ with the constraint $\int q(\mathbf{x}, \theta)$ $\mathbf{dxd}\theta = \mathbf{1}$. In fact, let the first term on the right side in Eq. (37.4) be $F(q(\mathbf{x}))$, then the maximization of the functional $F(q(\mathbf{x}, \theta))$ needs to maximize $F(q(\mathbf{x}))$, since $F(q(\mathbf{x})) = -\mathrm{KL}(\mathbf{q}(\mathbf{x}) \| \mathbf{Q}(\mathbf{x}))$, where $Q(\mathbf{x})$ can be approximated by $\exp[\langle \log p$ $(\mathbf{x}, \mathbf{y}|\theta) \rangle_{q(\theta)}]$ and the notation $\langle \cdot \rangle_{q(\cdot)}$ is represented as the expectation with density $q(\cdot)$. Therefore, solving the maximization $F(q(\mathbf{x}))$ can yield:

$$q^*(\mathbf{x}) = \mathbf{Q}(\mathbf{x}) \propto \exp[\langle \log \mathbf{p}(\mathbf{x}, \mathbf{y}|\theta) \rangle_{\mathbf{q}(\theta)}], \tag{37.5}$$

in the above notation $\propto$ refers to the achievement of equality with a normalizing constant. Similarly, consider that the model parameters θ can be decomposed by independent components. Accordingly, its density can be expressed by $q(\theta) = \prod_l q(\theta_l)$, so the variational posterior distribution of θ_l can be estimated as follows: $q^*(\theta_l) = Q(\theta_l) \propto p(\theta_l)\exp[\langle \log p(\mathbf{x}, \mathbf{y}|\theta) \rangle_{\mathbf{q}(\mathbf{x})\mathbf{q}(\theta_{-\mathbf{l}})}]$, where the $\theta_{-l} = \{\theta_1, \cdots, \theta_{l-1}, \theta_{l+1}, \cdots, \theta_N\}$. It can be seen that the above solution procedure can be computed iteratively until it converges. Actually, the above iteration procedure can be viewed as a special case of the expectation maximization (EM) algorithm, whereas the iterations terminate until the functional $F(q(\mathbf{x}, \theta))$ is converged.

2. Proposed Diagnostics and Prognostics Algorithm

In this section, the integrated ECLSS diagnostics and prognostics is presented based on the variational approximation. First of all, the prior distribution of the models parameters needs to be considered from the variational approximation scheme. Considered analytically intractable and with Bayesian properties, the conjugate prior is assumed which can be expressed as:

$$p(\pi) = \mathrm{Dir}(\pi; u^{\pi}), \quad p(A) = \prod_{i=1}^{N} \mathrm{Dir}(a_i; u_i^A), \quad p(C) = \prod_{j=1}^{N} \mathrm{Dir}(c_j; u_j^C),$$

$$p(\mu) = \prod_{k=1}^{K} \prod_{j=1}^{N} \mathscr{N}(\mu_{jk}; d_{jk}, D_{jk}^{-1}), \quad p(\Lambda) = \prod_{k=1}^{K} \prod_{j=1}^{N} \mathscr{W}(\Lambda_{jk}; v_{jk}, V_{jk}),$$

where, $\mathrm{Dir}(\cdot)$, $\mathscr{N}(\cdot)$, $\mathscr{W}(\cdot)$ are described as the DirichletGaussian and Wishart distributions respectively.

From the variational approximation principle, the conditional distribution of the observations with the given model's parameters and the hidden variables needs to be exploited to drive the posterior of the model's hidden variables. The hidden variables in our MoG-HMM-based trained models are the sequence s_t and the mixture component variables z_t which are shown as $\mathbf{x}$ in Eq. (37.2). To express the conditional distribution of the observations for the iteration procedure, it is assumed that the posteriors for the parameters are available from the previous iteration. For simplicity and clarity of presentation, the superscript "′" is use to describe the posterior of the model's parameter distributions obtained in the previous iteration, a tilde indicates an updated posterior for the parameter distributions, or a density of the condition observations and hidden variables. From Eq. (37.5), the likelihood of each observation y_t with a given hidden sequence and mixture component variables can be written as:

$$\widetilde{p}(y_t|s_t=j,z_t=k)\propto \exp[\langle \log \mathcal{N}(y_t;\mu_{jk},\Lambda_{jk}^{-1})\rangle_{q'(\mu_{jk})q'(\Lambda_{jk})}]$$
$$=\exp\bigg[-\frac{n}{2}\log 2\pi+\frac{1}{2}\langle \log|\Lambda_{jk}|\rangle_{q'(\Lambda_{jk})}-\frac{\widetilde{v}'_{jk}}{2}(y_t-\widetilde{d}'_{jk})^T\widetilde{V}'_{jk}(y_t-\widetilde{d}'_{jk})\bigg], \tag{37.6}$$

using the expressions, the follow densities can be computed: $\widetilde{p}(y_t|s_t)=\sum_{z_t}\widetilde{p}(y_t,z_t|s_t)=\sum_k\widetilde{c}_{jk}\widetilde{p}(y_t|s_t=j,z_t=k)$, notice that the $\widetilde{p}(z_t|s_t)$, corresponds to the parameters $\widetilde{C}=[\widetilde{c}_{jk}]\propto[\exp(\langle \log c_{jk}\rangle_{q'(c_{jk})})]$. In the variational approximation, the joint posterior densities of the hidden variables and the posterior densities of the distribution parameters interact and can be approximated iteratively until convergence. To implement the procedure, the forward and backward recursions need to be noticed. Utilizing the Markov properties of the models, the recursive formula can be given respectively as follows:

$$\alpha(s_t)=\widetilde{p}(s_t|y_{1:t})\propto\widetilde{p}(y_t|s_t)\sum_i\widetilde{a}_{ij}\alpha(s_{t-1}), \tag{37.7}$$

$$\beta(s_t)=\widetilde{p}(y_{t+1:T}|s_t)=\sum_j\widetilde{a}_{ij}\widetilde{p}(y_{t+1}|s_{t+1})\beta(s_{t+1}), \tag{37.8}$$

where, the updated parameters: $\widetilde{\pi}=[\widetilde{\pi}_i]\propto[\exp(\langle\log\pi_i\rangle_{q'(\pi_i)})]$, $\widetilde{A}=[\widetilde{a}_{ij}]\propto[\exp(\langle\log a_{ij}\rangle_{q'(a_{jk})})]$.

The initial conditions of Eqs. (37.7) and (37.8) are $\alpha(s_1)\propto\widetilde{p}(y_t|s_t)\widetilde{\pi}$, $\beta(s_T)=[1,\cdots,1]'$. The computing detail can be found in the appendices.

Using the above notations, the updated distribution of the health state at time, and the joint posterior for the two states in interval time can be yielded:

$$q^*(s_t)=\widetilde{p}(s_t|Y)=\frac{\widetilde{p}(s_t|y_{1:t})\widetilde{p}(y_{t+1:T}|s_t)}{\widetilde{p}(y_{t+1:T}|y_{1:t})}=\frac{\alpha(s_t)\beta(s_t)}{\sum_{s_t}\alpha(s_t)\beta(s_t)}, \tag{37.9}$$

$$q^*(s_{t-1},s_t)=\widetilde{p}(s_{t-1},s_t|Y)=\frac{\alpha(s_{t-1})\widetilde{p}(s_t|s_{t-1})\widetilde{p}(y_t|s_t)\beta(s_t)}{\sum_{s_t,s_{t-1}}\alpha(s_{t-1})\widetilde{p}(s_t|s_{t-1})\widetilde{p}(y_t|s_t)\beta(s_t)}, \tag{37.10}$$

similarly, the joint posterior for the two hidden variables is:

$$q^*(s_t,z_t)=\widetilde{p}(s_t,z_t|Y)=\frac{\widetilde{p}(y_t|s_t,z_t)\widetilde{p}(z_t|s_t)}{\widetilde{p}(y_t|s_t)}q^*(s_t). \tag{37.11}$$

The posterior distribution of the trained models parameters can be updated by exploiting the current densities of the hidden variables. Thus, for the different assumed priors of the MoG-HMM parameters, the following results can be achieved:

denote $q^*(s_t) = \tau_t = [\tau_{ti}]$, $q^*(s_{t-1}, s_t) = \eta_t = [\eta_{tij}]$, $q^*(s_t, z_t) = \omega_t = [\omega_{tjk}]$, then the Dirichlet posteriors for the initial distribution, the transition parameter, and the mixture components can be updated by:

$$q^*(\pi) = \mathrm{Dir}(\pi; \widetilde{u}^{\pi}), \quad q^*(A) = \prod_{i=1}^{J} \mathrm{Dir}(a_i; \widetilde{u}_i^{A}), \quad q^*(C) = \prod_{j=1}^{J} \mathrm{Dir}(c_j; \widetilde{u}_j^{C}),$$

where $\widetilde{u}_i^{\pi} = u_i^{\pi} + \tau_{1j}$, $\widetilde{u}_{ij}^{A} = u_{ij}^{A} + \sum_{t=2}^{T} \eta_{tij}$, $\widetilde{u}_{jk}^{C} = u_{jk}^{C} + \sum_{t=1}^{T} \omega_{tij}$.

For the Gaussian posteriors of the mixture component parameters, we have: $q^*(\mu_{jk}) = \mathscr{N}(\mu_{jk}; \widetilde{d}_{jk}, \widetilde{D}_{jk}^{-1})$, where, $\widetilde{D}_{jk} = D_{jk} + \widetilde{v}'_{jk} \widetilde{V}'_{jk} \sum_{t=1}^{T} \omega_{tjk}$, $\widetilde{d}_{jk} = \widetilde{D}_{jk}^{-1} (D_{jk} d_{jk} + \widetilde{v}'_{jk} \widetilde{V}'_{jk} \sum_{t=1}^{T} \omega_{tjk} y_t)$.

The Wishart posteriors for the parameter distribution matrices can be given by: $q^*(\Lambda_{jk}) = \mathscr{W}(\Lambda_{jk}; \widetilde{v}_{jk}, \widetilde{V}_{jk})$, where, $\widetilde{v}_{jk} = v_{jk} + \sum_{t=1}^{T} \omega_{tjk}$, $\widetilde{V}_{jk}^{-1} = V_{jk}^{-1} + \sum_{t=1}^{T} \omega_{tjk} (y_t - \widetilde{d}'_{jk})(y_t - \widetilde{d}'_{jk})^T + (\widetilde{D}'_{jk})^{-1} \sum_{t=1}^{T} \omega_{tjk}$. It can be seen that the posterior updating for the diagnosis model's parameters and the hidden state variables can be computed recursively. The termination condition can choose the variational free energy $F(q(\mathbf{x}, \theta))$ to converge or until the maximum number of iterations is reached.

After the above learning for the diagnosis models, the conditional observations representing different degradation stages are classified on the basis of the trained MoG-HMMs. Then, the identification of the ECLSS current health stages when the next observation is obtained need to exploit the observation likelihood to find the trained model that best fits with the current observations. Thus, the probability $P(y_{1:T}|\theta)$ under the different models parameters needs to be computed. For the trained models corresponding to the N health stages, let $\lambda_i^{(n)}(t) = P(y_{1:t}, s_t = i|\theta^{(n)})$ be the probability of the $y_{1:t}$ ending in state i under the trained model $\theta^{(n)}$, $n = 1, \cdots, N$, then the likelihood of the given observations $y_{1:T}$ can be written as: $\lambda_i^{(n)}(1) = \pi_i^{(n)} b_i^{(n)}(y_1)$, $\lambda_j^{(n)}(t+1) = [\sum_{i=1}^{N} \lambda_i^{(n)}(t) a_{ij}^{(n)}] b_j^{(n)}(y_{t+1})$, $P(y_{1:T}|\theta^{(n)}) = \sum_{i=1}^{N} \lambda_i^{(n)}(T)$.

For the integrated prognostics, the system RUL can be estimated using the diagnostics information. Taking into account the transition instant between the states, let D_i be defined as the duration of state i, then: $D_i \triangleq \sum_t E[I(s_t = i)] = \sum_t r_i(t)$.

From the posterior distribution of the state, the $D_i = \sum_t \tau_{ti}$. Given the Gaussian distribution assumption, the mean time duration μ_{D_i} and the standard deviation σ_{D_i} of the state can be estimated by:

$$\mu_{D_i} = \frac{1}{N} \sum_{t=1}^{N} (D_i)_t, \quad \sigma_{D_i} = \sqrt{\frac{1}{N} \sum_{t=1}^{N} [(D_i)_t - \mu_{D_i}]^2}.$$

Table 37.1 The number of training and testing data

Stages	S_0		S_1		S_2		S_3		S_4	
Learning	Training	Testing	Training	Testing	Training	Testing	Training	Testing	Training	Testing
Number	8	1	9	2	10	2	10	2	8	1

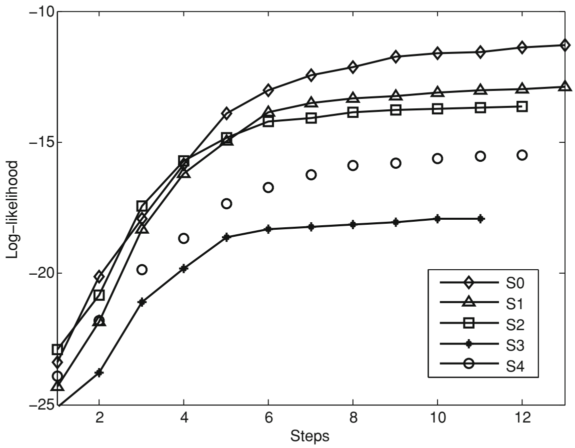

Fig. 37.2 The learning log-likelihood curve of different stages

37.5 Numerical Simulation

In this section, the integrated diagnostics and prognostics method presented previously was tested on a rich condition monitoring database taken from the test system containing different health stages simulated until failure. The diagnosis feature data was first classified through a health evaluation, then the different health stages which are most common in the ECLSS were identified and the prognostics results were determined using the diagnosis information for the new feature. The performance of the proposed variational approximation-based integrated diagnostics and prognostics was illustrated by a comparison with the existing methods based on the HMMs and HSMMs.

1. Diagnosis Models Training

On the basis of this evaluation information, the health stages represented by the monitored data which from the different subsystems were determined, so the corresponding feature data with known health conditions can be used for the MoG-HMMs training in the learning phase. In the two situations, the number of the training feature data and the test data under different situations are given in Table 37.1.

The log-likelihood through the training procedure in the proposed learning algorithm are given in Fig. 37.2.

Here, we compare the two existing methods with our method in which the first is the method based on the HMM in which the discrete parameters are learned using

Table 37.2 Diagnostics results based on three methods

Likelihood value	Test S_0	Test S_1	Test S_1	Test S_2	Test S_2	Test S_3	Test S_3	Test S_4
EM-HMM$_0$	−11.23	−inf	−inf	−inf	−inf	−inf	−inf	−inf
EM-HMM$_1$	−inf	−inf	−18.73	−inf	−inf	−inf	−inf	−inf
EM-HMM$_2$	−inf	−inf	−inf	−19.26	−12.21	−inf	−inf	−inf
EM-HMM$_3$	−inf	−inf	−inf	−inf	−inf	−21.93	−32.14	−inf
EM-HMM$_4$	−inf	−inf	−inf	−inf	−inf	−inf	−inf	−19.26
HSMM$_0$	−16.74	−32.65	−23.31	−17.78	−19.61	−28.67	−27.11	−17.64
HSMM$_1$	−21.41	−21.43	−17.36	−23.26	−29.14	−37.76	−32.73	−23.31
HSMM$_2$	−23.74	−38.21	−31.68	−14.87	−16.73	−43.71	−36.17	−34.18
HSMM$_3$	−27.35	−41.64	−38.97	−21.33	−31.12	−24.46	−23.57	−37.14
HSMM$_4$	−18.64	−35.38	−26.82	−19.23	−18.67	−32.65	−29.54	−13.72
MoG-HMM$_0$	−9.38	−17.63	−24.64	−17.14	−19.23	−23.16	−33.65	−19.34
MoG-HMM$_1$	−17.63	−16.45	−19.23	−21.76	−31.75	−36.77	−48.23	−23.47
MoG-HMM$_2$	−24.57	−32.28	−31.78	−11.68	−14.71	−34.84	−39.76	−21.68
MoG-HMM$_3$	−11.74	−43.67	−45.85	−28.44	−38.23	−17.65	−21.41	−31.63
MoG-HMM$_4$	−38.24	−21.34	−23.76	−16.28	−21.67	−21.36	−32.28	−14.76

Table 37.3 Mean and variance of RUL for different healthstates

Stages	S_0	S_1	S_2	S_3	S_4
RUL_{mean}	238.63	196.32	71.64	42.47	19.33
$RUL_{variance}$	1.65	1.24	1.87	2.41	1.56

the expectation maximization (EM) algorithm [1], and the second method was based on the Hidden Semi-Markov Models (HSMM) [2].

2. Diagnostics Results

The diagnostics results for the three different methods (EM-HMM, HSMM, MoG-HMM) are shown in Table 37.2. From Table 37.2, the log-likelihood values of the tested monitored observations under different trained models are yielded, thus, the system health stages are able to choose the diagnosis model with the maximum log-likelihood value. For the diagnostics results from situation1, the recognition rate based on the traditional HMM, which itself has been based on the EM algorithm is $7/8 = 87\,\%$, and the recognition rate based on the HSMM and the MoG-HMM with proposed variational approximation learning is $7/7 = 100\,\%$. Therefore, the new method is effective as a method based on HSMM, when the degradation models can be determined by fixed parameters.

Based on above diagnostics results, the statistical properties of the trained models representing four health stages can be obtained. The test data was generated randomly, thus the associated confidence value estimations can also be obtained. From these, the mean and variance of the duration in each state are also available using the prognostics algorithm. The results are given in Table 37.3.

37.6 Conclusion

An integrated diagnostics and prognostics for ECLSS in a manned-spacecraft has been presented in this paper. To implement the ECLSS health management at the system level, the proposed method makes full use of a health condition evaluation to diagnose the current health stages of the system, and predict the statistical properties of the RUL. In the proposed method, the feature data from different health stages are transformed to the corresponding MoG-HMMs, which take the feature as continuous observations. Different from the existing data-driven method based on parameter learning for the trained diagnosis models, the variational approximation-based technique is used to learn the distributions of the model parameters. Based on the diagnostics information of the trained models, the health stages are able to be identified when the next features are received, so the RUL and the associated confidence value estimations can also be obtained. Numerical examples demonstrated the effectiveness of the proposed integrated approach.

Acknowledgments The work is supported by China Postdoctoral Science Foundation (Grant No. 2013M542284).

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Chapter 38
Research on Big Data Under Enterprise Technological Innovation Management

Guichuan Zhou and Xiaowen Jie

Abstract From the actual needs of the enterprise in technological innovation management, this article is expected to figure out the practical problems in how to effectively fit in the new environment of "big data" era, how to heal with the ideological and technological revolution brought by "big data" to the traditional technological innovation management, and how to help the enterprise to achieve breakthroughs in technological innovation management. In order to fulfill this goal, the article with the latest research progress at home and abroad explores the impact of big data technology on enterprise in the way of technological innovation management and seeks new concepts on the basis of big data technology to address the problems in technological innovation management of the enterprise, expecting to give support to practical work of the enterprise in terms of technological innovation management.

Keywords Big data · Technological innovation · Innovation management

38.1 Introduction

"Big Data" as the buzzword has attracted the attention of industry insiders, coupled with data warehouse, data security, data analysis, data mining and other commercial applications of big data. The U.S. Internet Data Center noted that the data on the Internet grows by 50 % annually and doubles every two years, and more than 90 % of the data worldwide came into being in recent years, especially after the year of 2009 [2].

Although the business data is valuable, the strategic significance of big data technology is reflected in specialized processing of these meaningful data, instead of the

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_38,

grasp of huge data information as for most enterprises, especially those engaging in technological innovation. If the big data is compared to the technological resource, the key to giving full play to such a technological resource is to improve "processing capacity" of the dada and realize "added value" of the data through "processing".

Therefore, this article from the actual needs of the enterprise in technological innovation management is expected to figure out the practical problems in how to effectively fit in the new environment of "big data" era, how to deal with the ideological and technological revolution brought by "big data" to the traditional technological innovation management, and how to help the enterprise to achieve breakthroughs in technological innovation management. In order to fulfill this goal, the article with the latest research progress at home and abroad explores the impact of big data technology on enterprise in the way of technological innovation management and seeks new concepts on the basis of big data technology to address the problems in technological innovation management of the enterprise, expecting to give support to practical work of the enterprise in terms of technological innovation management.

38.2 Literature Review

1. Big Data

According to McKinsey Global Institute, big data is the term for a collection of data sets so large and complex that it becomes difficult to process using on-hand database management tools or traditional data processing applications. The big data is featured by 5 Vs. The first one is volume, i.e. the increasing amount of data. The data of Baidu showed that its home page is required to provide the data of more than 1.5 PB (1 PB = 1,024 TB) everyday and the printouts of these data will exceed 500 billion pieces of A4 paper. It is confirmed that the total amount of data from printed materials is only 200 PB so far. The second is variety, i.e. diversified data types. In addition to the text, the data types include picture, video, audio and geographical information with overwhelming amount of the individualized data. The third feature is velocity, i.e. fast processing speed. The data processing follows the rule of "one-second response time", allowing the users to quickly obtain high value information from various types of data. The fourth one is known as value, i.e. low value density. In the one-hour video, for example, the continuous monitoring may only capture one to two seconds of useful data. The last one is veracity, i.e. accurate analysis results. By massively parallel processing (MPP) database, data mining grid, distributed file system, distributed database, cloud computing platform, the Internet, scalable storage system and other technologies of big data, the users can access to valuable information from a variety of data types [5].

Since 2008, the research on big data has witnessed a rapid development in China and reached a peak in the last three years. According to Zhu et al. [8], the research focusing on "Big Data" and "Cloud Computing" with the keywords of "Computer" and "Software Technology" accounts for more than half of the studies. However, as the big data is increasingly influential in enterprise management, the keywords of “Data Management”, “Data Grid” and “Ontology” appeared in a large number of studies centering on “big data” management. Nevertheless, the research of “big data” at home and abroad still pays much attention to the big data technology and software application in storage, processing, analysis and management, while there is scarcely any study combining “big data” with applied management, especially with technical management.

2. Big Data and Enterprise Technological Innovation

Since Schumpeper proposed technological innovation in well-known “Theory of Economic Development”, more and more enterprises have attached importance to restructuring of production factors, conditions and organizations to establish an efficient production system to earn high profits [7]. The emergence of big data technology is expected to greatly improve the efficiency of enterprise technological innovation. On the one hand, big data technology has brought new means of technological innovation management, allowing enterprises to analyze the behavioral data through real-time monitoring and follow-up study of technological innovation activities, uncover the underlying regularities, find the problems and put forward solutions. On the other hand, Krishnan et al. [3] and other scholars noted that the big data is able to hasten the organizational reform under the condition of rigorous data management, insightful data analysis, and motivated management innovation environment. Thirdly, the application of big data is crucial for enterprises to enhance the core competitiveness, for the decision making of technological innovation has been driven by data instead of business currently. The analysis on big data not only enables the enterprises to grasp and respond to market dynamics quickly, but also helps them to timely provide personalized products and services through technological innovation.

38.3 Big Data Technology Under Enterprise Technological Innovation Management

From the technological innovation practice of the enterprises, some of them introduced advanced technology or technological equipment to improve their technological level; some companies integrated the technological advantages of cooperators to realize cooperative technological innovation; and there are also enterprises that invested in technological innovation for technology creation and product research and development to achieve cooperative technological innovation with intellectual property right. Accordingly, enterprise technological innovation can be divided into technology introduction, technology integration and technology creation.

1. MPP Technology at the Level of Technology Introduction

Technology introduction, at a lower level in cooperative technological innovation, refers to the enterprise introduces advanced and applicable technology from other companies through a certain way. Generally, there are five ways in technology introduction. Firstly, introduce technology and manufacturing technique, technical knowledge and data (including product design, material formulation, manufacturing drawing, technological process, technological testing methods and maintenance), as well as technical service by hiring experts and entrusting training staff. Secondly, introduce complete equipment, key device and detection means in addition to technology. Thirdly, introduce modern management method and give full play to the introduced technology, attaching importance to the knowledge in both technology and management. Fourthly, introduce advanced innovative ideas and scientific and technological knowledge through technical exchange and cooperation, academic exchange and technology exhibition, etc. Fifthly, introduce technical personnel. The technology introduction is expected to eliminate the technology gap and improve technological level of the enterprise fundamentally in a long term; and the short-term goal is to fill in the technology gap of the enterprise from the production requirements.

It is noteworthy that the technology introduction should give top priority to technology identification. The enterprise has to identify those advanced, applicable and feasible technologies before introduction, so that it can absorb the introduced technology and carry out technological innovation under the existing technological level. As for the enterprises, insufficient technicians and weak technological base usually indicate the insufficient technical information and weak technological identification ability. In this sense, the enterprises can resort to more advanced big data technology, which will be greatly helpful in decentralized processing of massive technical information.

Massively Parallel Processing (MPP) database system is able to divide the collected alternative technologies into independent data blocks managed by isolated storage and CPU, breaking the constraint that the massive technical data can only be managed by centralized research and development center. The data in technological innovation system will be distributed to different servers and stored in various departments involving different links of technological improvement.

Although MPP system will cause data redundancy to a certain extent, it is helpful in data recovery once the system failure happens by storing the same data in different departments involving technological improvement. At the same time, resource management tools in MPP will assist departments involving different links of technological improvement in managing the massive technical data, of which technical query optimizer will optimize various technical query tasks to improve computational efficiency.

The identification ability tends to determine whether the technological innovation of the enterprise is able to go smoothly, achieve success and create commercial value, etc. MPP technology will directly affect the accumulation of technological knowledge of the enterprise, have an impact on knowledge architecture of technological innovation and concern the performance of technological innovation eventually (Fig. 38.1).

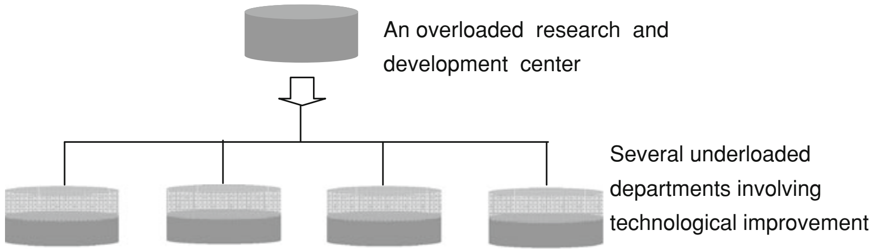

Fig. 38.1 MPP technology and enterprise technology introduction

2. Cloud Computing Technology at the Level of Technology Integration

Generally, technology integration as a new means of technological innovation indicates that the enterprise evaluates and chooses the suitable technologies systematically to integrate with the existing technologies during the process of technology or product research and development, so as to create new products or new technologies.

As the subject of technological innovation, it is not easy for the enterprises to own technical capacities of different disciplines and industries, while technological innovation that is able to integrate advanced technologies of all industries is the best solution. The technical expertise, management knowledge, production technology, materials technology, process program, equipment system, standardized technology, information technology and management control technology owned by enterprises in all sectors are the source of technological innovation. The enterprise can select the required technologies as the supplement from various disciplines, categories and professional fields and integrate them with existing technologies, so as to fulfill the objectives of technological innovation.

With the rapid development of science and technology, the resources of enterprise technological innovation become increasingly decentralized and thus more and more companies began to attach great importance to the external integration of a variety of technological resources. The companies tend to strengthen the contacts from the perspective of technology with external organizations including their competitors, expecting to realize technological innovation through integration of resources and complementation of technologies.

Since the emergence of cloud computing technology, enterprise technological innovation is facing a growing number of cloud environments. As the underlying hardware of the cloud computing can be anywhere geographically, the enterprises can enjoy the cloud computing services by only paying operating costs according to usage amount, dispensing with infrastructure construction or fixed capital. There are various hardware rental models of cloud computing, allowing different enterprises to share the services and accordingly the rental costs. What's more, the system capacity of cloud computing is scalable in a very short time, while the traditional hosting services are restricted by scalability of the system. Therefore, cloud computing has shown a remarkable strength (Fig. 38.2).

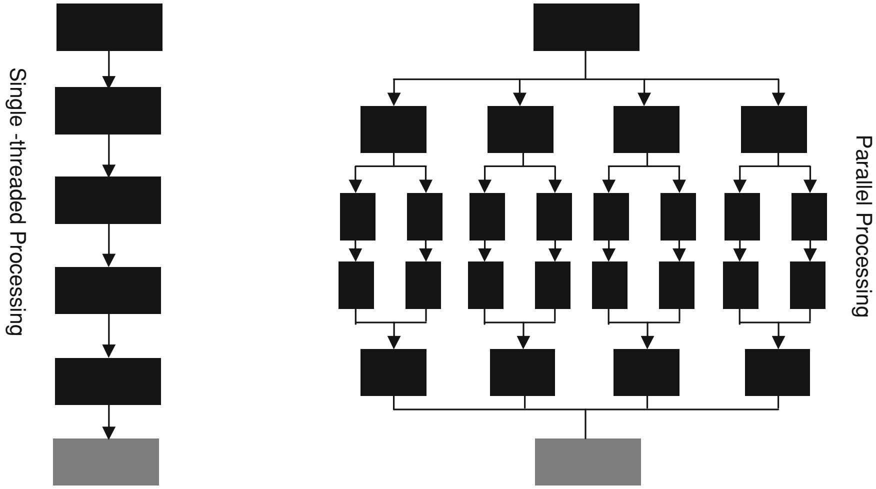

Fig. 38.2 Comparison between traditional query and MPP query

From the application practice of cloud computing, it consists of two types, i.e. public cloud and private cloud. For users of public cloud, they can upload the technical data to an external cloud computing system and access to the resources allocated by the system for technical data processing, with the charging standard of usage amount. This mode not only helps the enterprises to save the cost in construction of technical resource system, but also allows them to obtain new technical resources quickly. As the technical data is stored in the system outside the enterprise firewall, technical data sharing between different enterprises becomes simple and each enterprise can be authorized to login and access to the technical data. However, the public cloud will not make a commitment in performance, handling time and more importantly the data security.

Private cloud is almost the same as the public cloud, except that the private cloud is owned by an enterprise and runs inside the corporate firewall. With exactly the same services as the public cloud, the private cloud only gives service to the enterprise's internal staff and team. As for the obvious advantage of this type of cloud computing, the enterprise is able to fully control the private cloud, including the security of technical data and system. Of course, the enterprise has to pay for a set of cloud computing device and bear the risk of idle resources of the system in most of the time.

The technology integration through enterprise technological innovation has to be based upon strong technological cooperative capability. Cloud computing technology allows the enterprise to closely cooperate with its partners to take the advantage of external technology, reduce transaction costs in technology, improve the specialization of technology, strengthen collaborative innovation, spread the risk of technological innovation and avoid vicious competition in the cooperative organization of technological innovation connected by the interests. Besides, with the help of cloud computing technology, the information can spread quickly and efficiently to achieve resource sharing in both knowledge and technology, so that the

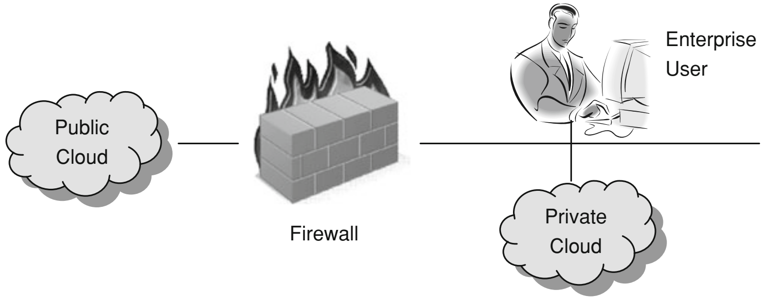

Fig. 38.3 Comparison between public cloud and private cloud

enterprise can not only obtain new knowledge and new technology at a low cost, but also transform the technological superiority by integrating the new technology with the existing technology to technological competitiveness, hereby maximizing the efficiency and the benefits of enterprise technological innovation (Fig. 38.3).

3. MapReduce Technology at the Level of Technology Creation

The highest level of enterprise technological innovation is the technology creation which is featured by the technologically leading position of the enterprise.

In order to achieve a breakthrough in technology, the enterprises are likely to establish R&D team, project group, joint venture and other professional organizations involving in technological innovation. On that basis, the enterprises tend to invest heavily in technological innovation to enhance technical competence and expect to obtain unique technologies and products with competitive edges.

In order to achieve a qualitative leap technologically through technological innovation, the enterprises are required to establish a model with new elements of innovation and go through the process of "creative destruction" to achieve the goal of technology creation. In this process, the enterprises have to develop predictive ability, so as to create new technologies that bring competitive advantages for enterprises or develop resource-based products that meet the needs of market and obtain higher economic benefits.

As a new type of strategic management capacity, technology-related predictive ability is the important means for enterprises to realize technological, economic and social integration, as well as the ability to effectively carry out the resource combination and optimal configuration. It is helpful for enterprises to develop scientific strategic plan of technological innovation and on that basis the enterprises are allowed to utilize the results of technological prediction, analyze the changes of market demand and thus find the information technology and technological opportunity in favor of technological creation. Based on technological prediction, the enterprises are also able to accurately identify the market need to prepare for the next competition, develop or adjust the direction of technological innovation, and create new technology in line with market demand and development tendency.

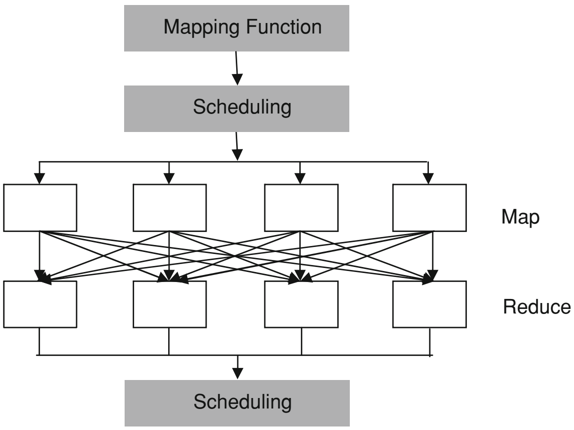

Fig. 38.4 Execution of MapReduce

MapReduce technology in the era of big data is a parallel programming framework and is helpful for R&D personnel of the enterprises with the processing of massive technical data, especially in two key links: “map” and “reduce”, which will be executed concurrently in a series of nodes of technological innovation. Unlike MPP system, information exchange will not happen between these nodes, reducing information interference for R&D staff.

Currently, more and more enterprises have found that it is crucial to analyze constantly generated massive technical data to support technological innovation and decision making and MapReduce technology is able to help technical personnel to manage massive semi-structured or unstructured technical data.

In the process of technological innovation, MapReduce technology will provide the useful information for technical management personnel through two steps. The first is “map” step. Since the technical data of enterprise is continuously written in the system, analysts can analyze every key data recorded in the text by establishing the mapping program that is able to search the data from the text, parse the data from the paragraph, and then do a word count. The next step is “reduce”. Through reduction operation, the results output by mapping program in different nodes will be collected for secondary allocation. By outputting the results of technical data processing, technical management personnel is able to identify and focus on the key information in the process of technological innovation, so as to seek breakthroughs in key links of industry technology (Fig. 38.4).

MapReduce technology is able to help the companies to improve technology-related predictive ability, effectively invest in technical resources, predict the development trend of technology and product, and hereby guide the technological innovation.

38.4 Big Data-Related Approaches in Improvement of Enterprise Technological Innovation Management

As for the enterprises in the era of big data, they can achieve technological innovation by improvement of big data technology. Objectively, some of the companies restricted by their own conditions can't improve the big data technology. Therefore, the approaches in improvement of big data technology may not exactly the same and the enterprises on the basis of their conditions should upgrade big data technology and enhance the management of technological innovation in a planned and orderly way [4].

1. Breakthrough Approach in Improvement of Big Data Technology

Breakthrough approach in improvement of enterprise technological innovation refers to the enterprises can take MPP, cloud computing, grid computing, MapReduce and other technologies that are easy to make progress as a breakthrough and improve the performance of the enterprise technological innovation by upgrading the data analysis technique.

Requiring the enterprise to have the advantages in a certain aspect, this approach is able to maximize the strengths of the enterprise and transform them to favorable terms required by the big data technology. Besides, it highlights the key points of management and it is easy to control. However, the development environment is changeable and thus the advantages of enterprises will not last for a long time, especially some of the companies lack the core competitiveness with only relative and limited competitive edge. Therefore, it is risky and unsustainable to develop big data technology merely by the superiority in one aspect.

2. Parallel Approach in Improvement of Big Data Technology

Parallel approach in improvement of enterprise technological innovation from the perspective of management allows the companies to coordinate technical resources from different sources, improve big data technology concertedly and thus enhance the performance of enterprise technological innovation significantly. This approach promotes the interaction of big data technology in different enterprises and effectively carries out technological innovation with the means of parallel development, so as to accelerate synergies between enterprises and launch technological innovation activities more efficiently.

Parallel improvement of performance requires the enterprises involving in technological innovation to enhance capabilities of internal data analysis and focus on improvement of external data environment, knowledge sharing and technology exchange between cooperators.

The advantage of parallel approach in improvement of performance lies in synergies, to be exact, the enterprises can mobilize all resources in favor of improvement of big data technology to achieve the effects of $1 + 1 > 2$. In the process of technological innovation, data analysis techniques of different enterprises are not the same, which is conductive to reinforcing complementary advantages and thus promoting cooperation between enterprises.

3. Vertical Approach in Improvement of Big Data Technology

Vertical approach is the most advanced way to promote big data technology of enterprise, which enables the companies to fully integrate the advantages in various fields and comprehensively improve each factor that may affect data analysis technique, so as to substantially upgrade the technological innovation.

According to the vertical approach, the enterprises are required to aggregate technological data and innovative resources to the maximum extent, analyze and process the data in a highly coordinated way, as well as maximize synergies in selection of technical direction, cooperation of technology research and development and allocation of technological achievements, so as to enhance the performance of technological innovation roundly.

With respect to the difficulties of technological innovation management, the vertical approach in improvement of big data puts forward higher requirements for enterprise technology innovation obviously. In order to promote the big data technology with this vertical approach, the enterprises need to abide by the following principles in the process of technological innovation:

Principle of Multi-objective Development: data analysis should pursue economic, technological and social benefits. Economic benefit indicates that big data technology of the enterprise has to maximize the value of technological innovation; technical benefit implies that the big data technology helps to improve the technological capabilities of the enterprise and create the advanced and transformative technological achievements with technological content; and social benefit requires the big data technology to avail social harmony, as well as economic and scientific development.

Principle of Coordinated Development: the enterprises are required to focus on the coordination of business interests in the process of organizing and participating in the improvement of big data technology. Enterprises embrace benefit maximization and thus the management activities are also driven by interests. However, the vertical approach in improvement of big data technology asks for maximum coordination between speed and quality with respect to the development of big data technology.

Principle of Sustainable Development: big data technology of the enterprises should go after sustainable development in technology, economy and natural ecology. The development of big data technology is expected to promote cleaner and more advanced production technology with high-tech products, as well as the sustainable development of technological innovation eventually.

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Chapter 39
Application of Multi-objective Optimization Based on Genetic Algorithms in Mining Processing Enterprises

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Abstract Mining industry has been the pillar industry of the economic and social development but it is also an industry with high level of pollution and emission. Modern mining enterprises not only manage to maximize the economic benefits, but also consider environment protection while they make decisions. In order to solve the problem, we apply Genetic Algorithms (GA), which is most commonly used in Multi-objective optimization. However, the probability of crossover and mutation is a fixed value in common genetic algorithms. In this paper, we use auto-tuning strategy to adjust these probabilities, which means adjust the values by fitness function. We have taken the importance of environmental protection into account in the mathematic model. So the model can be widely used in other enterprises with high level of pollution and emissions. In the policy of sustainable development of China, the model is universal and objective.

Keywords Mining processing enterprises · Genetic algorithms · Multi-objective optimization · Auto-tuning strategy

39.1 Introduction

As we know, mineral is a kind of non-renewable and depletive resource, the value of which is derived from the usefulness and the scarcity. As a pillar industry of China, Mining industry plays an important role in economy and make significant contribution to the development of economy. Mineral resource is an important material basis for economic and social development. According to "China Sustainable Energy Development Strategy", more than 90 % of China's primary energy, 80 %

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_39,

of industrial raw materials, 70 % of agricultural production and 30 % of domestic water are derived from mineral resources. In 2007, there are over 100,000 mining companies, 6 billion tons of mined ore and more than 8 million employees. In 2012, the values of import and export trade of mineral are $494.2 billion, which increase by 3.4 %. However, the development of mineral resources also have negative effect on the environment. For example, in process of mining, mineral separation, smelting, exploitation of mineral resources causes widespread environmental pollution, including pollution of heavy metal, corrosive and radioactive substance, toxic chemicals and radioactive substance. These substances pollute soil and water, indirectly poisoning the human body through the food chain. Therefore, mining processing enterprises not only need to produce in accordance with the goal of economy, but also pay attention to environmental protection and minimize waste gas and waste water emissions as best as they can. In this paper, we use GA and auto-tuning strategy to solve the mathematic model.

Multi-objective optimization problem and GA have been a problem and a hot issue in the field of science and engineering research. In the past 20 years, the genetic algorithm attracted a lot of attention as a multi-objective optimization method. In the 1990s, genetic algorithms was applied to multi-objective optimization field. In 1985, in order to overcome the disadvantages of the methods of integration, David [1] proposed a kind of genetic algorithm (VAGA) based on vector assessment on the basis of a single-objective optimization program GENESIS of Grefentette. In 1993, Fonseca and Fleming [4] proposed a multi-objective optimization algorithm. In the same year, Horn and Nafpliotis proposed a tournament selection method based on Pareto dominance definition, i.e. winning team GA [5]. In 1995, Srinvas and Deb [7] proposed NSGA. In 1999, Eckart Zitzler proposed Strength Pareto Evolutionary Algorithm [3]. In 2000, Deb proposed an improved algorithm (NSGA-II) [2]. As multi-objective optimization algorithm was applied in more and more fields, its research will be directly driven by practical engineering problems.

Auto-tuning strategy has been used in past few years in different field, such as heating furnace system and random early detection. Adaptation techniques of EA have been proposed during the past few years. Problem adaptation and evolutionary processes adaptation are two kinds of different adaptations. Normally, a lot of applications of EA have fixed the parameters, so it is in contrast to the general determination of EA. Thus it is a natural idea to adjust the values of parameters during the run of algorithm [6].

39.2 Problem Description

Mineral is a kind of non-renewable and depletive resource, the value of which is derived from the usefulness and the scarcity. Mining industry plays an important role in economy and make significant contribution to the development of economy. But at the same time, it is urgent to take action on environmental issues. There are a large number of state-owned or private enterprises mining and processing mineral

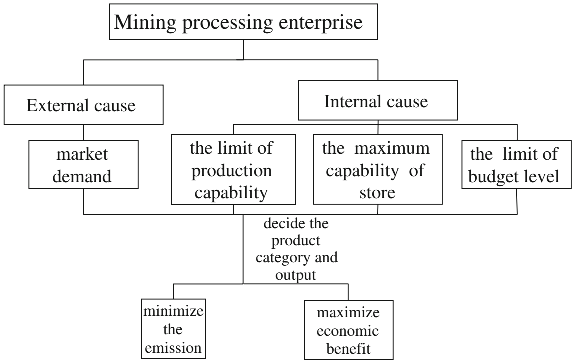


Fig. 39.1 The relationship between the operation constraints and the objective of the mining processing enterprise

production in some area rich in mineral resources. Since many mineral resources are scarce and polluted, enterprises need to take environment protection into account while they are pursuing the maximization of the economic benefits. Optimization effect of cost will directly affect the economic benefits because there are fixed costs and variable costs. Mineral resources are not fully converted into products at the limit of technology. At the same time, there is maximum limit of production capability which the output cannot exceeds. But the output should not be less than the market demand. As for enterprises, they need to decide the type and output of the products under these constraints (Fig. 39.1).
Assumptions:

1. The emission of waste water and waste gas of mining processing enterprises is proportional to the number of mineral raw materials, which are used for the production of products.
2. There are certain limitations of the production capability.
3. Conversion rate is a fixed value.

Notations:

X_i mineral usage amount of each product
Θ_i conversion rate of each product
t_i unit cost of each product
h inventory cost
C_i unit price of each product
n number of product category
ed_i emission coefficient of waste gas of each product
ew_i emission coefficient of waste water of each product
P_i market demand of each product
IV the maximum limit of inventory
Y the maximum limit of mineral product that can be produced
PC Production cost budget.

39.3 Mathematical Model

Mineral processing enterprises regard economic profit maximization as the aim of priority. In addition, they need to consider emission minimization, because the emissions of the mining processing enterprises do harm to the environment. Moreover, because of the limit of production capability and inventory, exploitation of mineral resources and production costs faced with restrictions, and the output should not be less than the market demand.
The first goal is to maximize the economic benefits considering the production cost function,

$$\max H = \sum_{i=1}^{n} C_i \Theta_i X_i - \sum_{i=1}^{n} f(X_i) - h\left(Y - \sum_{i=1}^{n} x_i\right), \tag{39.1}$$

where the production cost function is defined as follows,

$$f(x) = \begin{cases} t_i X_i, & X_i > 0 \\ 0, & X_i \le 0. \end{cases} \tag{39.2}$$

The second objective is to minimize emissions. The emissions of a enterprise include waste gas and waste water.

$$\min K = \sum_{i=1}^{n} (ed_i X_i + ew_i X_i). \tag{39.3}$$

The total mineral resources which will be used cannot exceed the maximum capability of the enterprise, $\sum_{i=1}^{n} X_i \le Y$. Mineral resources that are not used can not exceed the maximum limit of the inventories, $Y - \sum_{i=1}^{n} X_i \le IV$. The total cost of production, including production and inventory costs, shall not exceed the enterprise budget, $\sum_{i=1}^{n} f(X_i) + h(Y - \sum_{i=1}^{n} x_i) \le PC$. Quantities of mineral products shall not be less than the market demand, $\Theta_i X_i \ge P_i$.

In short, the total optimization model for allocating mineral resources is summarized as follows:

$$\begin{aligned} \max H &= \sum_{i=1}^{n} C_i \Theta_i X_i - \sum_{i=1}^{n} f(X_i) - h\left(Y - \sum_{i=1}^{n} x_i\right) \\ \min K &= \sum_{i=1}^{n} (ed_i X_i + ew_i X_i) \end{aligned}$$

$$\text{s.t.} \begin{cases} \sum_{i=1}^{n} X_i \leq Y \\ Y - \sum_{i=1}^{n} X_i \leq IV \\ \sum_{i=1}^{n} f(X_i) + h\left(Y - \sum_{i=1}^{n} x_i\right) \leq PC \\ \Theta_i X_i \geq P_i. \end{cases} \tag{39.4}$$

39.4 Auto-tuning Parameters-Based GA

In general GA, we used to regard the probability of crossover and mutation as a given number. However, in the process in the crossover and mutation, the probabilities need to be adjusted. Therefore, in this paper, the probabilities are updated continually by auto-tuning strategy.

39.4.1 Auto-tuning Strategy

If it consistently produces a better offspring, the average fitness change in parents and offspring populations during continuous generations of GA increases the occurrence probability of mutation operation (P_m) and decreases the occurrence probability of crossover operation (P_{λ_i}). Otherwise, it decreases the occurrence probability of P_m and increases the occurrence probability of P_{λ_i}, if it consistently produces a poorer offspring during the generations. The change of the average fitness at generation t, $\Delta\text{eval}_{\text{avg}}(t)$ can be set as follows:

$$\Delta\text{eval}_{\text{avg}}(t) = \left(\frac{1}{\text{parsize}} \sum_{k=1}^{\text{parsize}} \text{eval}_k(t) - \frac{1}{\text{offsize}} \sum_{k=1}^{\text{offsize}} \text{eval}_k(t) \right), \tag{39.5}$$

where parsize and offsize are the parent size and offspring size, respectively.

39.4.2 Crossover and Mutation

1. Calculate the possibilities of crossover and mutation operation.
   Calculate the changes of the crossover rate $\Delta P = P \times Z(i, j)$, and the mutation rate $\Delta P_m = P_m \times Z(i, j)$, where the contents of $Z(i, j)$ are the corresponding values of $\Delta\text{eval}_{\text{avg}}(t)$ and $\Delta\text{eval}_{\text{avg}}(t-1)$, for defuzzification (see Tables 39.1 and 39.2).

Table 39.1 Input and output results of discrimination

Input	Output
$w \le -0.7$	−4
$-0.7 \le w \le -0.5$	−3
$-0.5 \le w \le -0.3$	−2
$-0.3 \le w \le -0.1$	−1
$-0.1 \le w \le 0.1$	−0
$0.1 \le w \le 0.3$	−1
$0.3 \le w \le 0.5$	−2
$0.5 \le w \le 0.7$	−3
$w \ge 0.7$	−4

Note $w = \Delta\text{eval}_{\text{avg}}(t-1)$ or $w = \Delta\text{eval}_{\text{avg}}(t)$; outputs = i or j

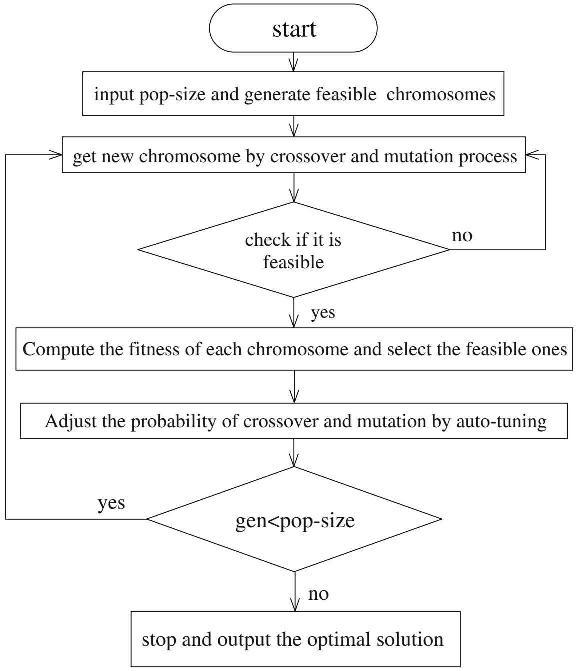
Table 39.2 Defuzzification table for control action for crossover and mutation ratios

$Z(i, j)$		i								
		−4	−3	−2	− 1	0	1	2	3	4
j	− 4	− 4	−3	− 3	− 2	− 2	− 1	− 1	0	0
	− 3	− 3	− 3	− 2	− 2	− 1	0	0	1	1
	− 2	− 3	− 2	− 2	− 1	− 1	0	0	1	1
	− 1	− 2	− 2	− 1	− 1	0	0	1	1	2
	0	− 2	− 1	− 1	0	2	1	1	2	2
	1	− 1	− 1	0	0	1	1	2	2	3
	2	− 1	0	0	1	1	2	2	3	3
	3	0	0	1	1	2	2	3	3	4
	4	0	1	1	2	2	3	3	4	4

Then update the change of the rates of the crossover and mutation operators by using the following equations: $P_{\lambda_i}(t) = P_{\lambda_i}(t-1) + \Delta P_{\lambda_i}$, $P_m(t) = P_m(t-1) + \Delta P_m$.

2. Crossover operation:
   Generate two random numbers λ_1, λ_2 from the open interval (0, 1) satisfying $\lambda_1 + \lambda_2 = 1$. The chromosome X_i is selected as a parent provided that $\lambda_i < P_{\lambda_i}$, where parameter P_{λ_i} is the probability of crossover operation. Repeat this process $N_{\text{pop-size}}$ times. $P_{\lambda_i} \cdot N_{\text{pop-size}}$ chromosomes are expected to be selected to undergo the crossover operation. The crossover operator on X^1 and X^2 will produce two children Y^1 and Y^2 as follows: $Y^1 = \lambda_1 X^1 + \lambda_2 X^2$, $Y^2 = \lambda_1 X^2 + \lambda_2 X^1$.
   If both children are feasible, then we replace the parents with them; otherwise we keep the feasible one if it exists. We repeat the above operation until two feasible children are obtained or a given number of cycles are finished.
3. Mutation operation:
   Like in the crossover process, the chromosome X^i is selected as a parent to undergo the mutation operation provided that random number $m < P_m$, where parameter P_m is the probability of the mutation operation. $P_m \cdot N_{\text{pop-size}}$ chro-

Fig. 39.2 Flow chart for GA



mosomes are expected to be selected after repeating the process $N_{\text{pop-size}}$ times. Suppose that X^1 is chosen as a parent. Choose a mutation direction $d \in R^n$ randomly. Replace X with $X + M \cdot d$, if $X + M \cdot d$ is feasible; otherwise set M as a random between 0 and M until it is feasible or a given number of cycles are finished. Here, M is a sufficiently large positive number.

39.4.3 Steps

In summary, flow of the Algorithm can be expressed as follows (see Fig. 39.2).
Step 1. Input pop-size.
Step 2. Generate and initialize chromosome that fit these constraints.
Step 3. Get new chromosomes by cross and mutation process. The possibility of cross and mutation is adjusted by using auto-tuning strategy.
Step 4. Use regret function, which is defined as the distance between the points and the ideal solution, to calculate the fitness. Choose chromosomes with higher fitness.
Step 5. Repeat the three and four steps for a given number of cycles.
Step 6. Output the optimal solution and value.

Table 39.3 Basic data of the business condition

Mineral species	Copper	Plumbum	Aluminum
Product	Cathode copper	Electrolytic lead	Electrolytic aluminum
Unit price (yuan/ton)	55,275	16,995	16,480
Unit cost (yuan/ton)	19,279.92	3,427.362282	7,264.56289
Maximum production capacity (ton)	62,000	120,000	112,000
Market demand (ton)	59,185.7346	106,550.1431	70,579.057
Resource conversion (%)	99	90	99.2
Emission coefficient of waste water	1.97740113	2.543088881	0.819672131
Emission coefficient of waste gas	0.621468927	0.598175059	0.409836066
Maximum limit of inventory (ton)		200,000	
Unit inventory costs (yuan/ton)		281.741517	
Budget of cost (yuan)		9,376,274,767	

39.5 Case Study

Chinese mining companies usually produce kinds of products at the same time. So they need to decide the types and output of products and adjust the allocation of mining resources, in order to optimize the goal of economic efficiency and pollution emissions. In this paper, we will take the basic non-ferrous metal industry sector as an example to research the optimal production decisions.

39.5.1 Basic Condition

Company A is a large integrated mining processing company listed on the main industry in the development of mineral resources, which are mainly engaged in smelting, trade and other business of copper, lead, zinc, aluminum, iron and other base metals, ferrous metals and non-metallic mining phosphate ore. The company owns more than ten million tons explored resources, eight mines and five smelters. The non-ferrous metals mining industry sectors of the company including processing, smelting and other services of copper, lead, aluminum and other non-ferrous metal products. In order to describe the case in a convenient and simple way, we choose three non-ferrous metal products with maximum output to analysis the Multi-objective optimization problem. Each non-ferrous metals will be processed in electrolysis way and be turned into only one product. Here are some data related to the business condition of the company (Table 39.3).

39.5.2 Solution Approach

Step 1. Randomly generate a chromosome. Check whether it satisfies the cost of production, inventory caps, market demand and other constraints. If is not satisfied, then regenerate the chromosome and check it again.

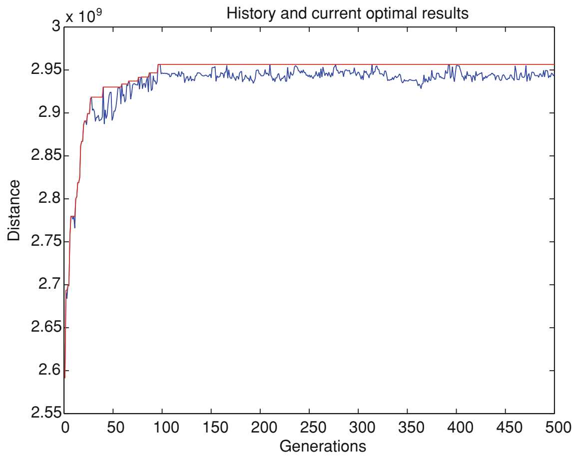


Fig. 39.3 History and current optimal results

Step 2. Calculate the fitness. Fitness value is measured by regret function, which is defined as the distance between the points and the ideal solution. Then pick out chromosome with the larger fitness.
Step 3. Calculate the probability of crossover and mutation. In general, the probability of crossover and mutation is a given value. But in this paper, crossover and mutation probability is calculated by auto-tuning strategy, which means that the probability is adjusted by itself in the process of the algorithm.
Step 4. Get new chromosomes by cross and mutation process with calculated probability.
Step 5. Check if the new chromosomes fit these constraints.
Step 6. Repeat step 2–5 for a given number of cycles. After finishing that, stop the program and get the optimal solution.

39.5.3 The Results

We can see the history and current optimal conditions, as well as the conditions of convergence (see Fig. 39.3). The results show that it converges after the 50th generation. The speed of the convergence is relatively fast. And the condition of the convergence is very good. After finishing calculating, we get that $X_1 = 82,110$, $X_2 = 119,340$, $X_3 = 71,880$. Which means the optimal choice for the enterprise is to produce 82,110 t of Cathode copper, 119,340 t of Electrolytic lead and 71,880 t of Electrolytic aluminum.

And the values of the optimal objective function are $H = 4,979,253,946.1$, $K = 676,630.553$, which is the best result of this problem.

39.6 Conclusion

Modern enterprises should regard reducing emissions as one of the business objectives of its sustainable development while they usually consider maximizing economic benefits as the most important goal. In the process of realizing the multi-objective optimization, genetic algorithms is one of the most widely used methods. We usually see the probability of crossover and mutation as a given value and we cannot change it. But in actual situation, the probability often need to be adjusted by itself. The strategy of auto-tuning can realize that. And we have already proved that in the case study, so the auto-tuning strategy is a useful method which can be widely applied in multi-objective optimization problem in variety situations.

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).

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Chapter 40
Input Analysis in Simulation: A Case Study Based on the Variability in Manufacturing Lines

David Lucas and Alexandra Tenera

Abstract Simulation is a powerful tool with acknowledged capabilities that has proved to be a valuable support instrument to decision making. In order to attain a proper representation from the system, it's necessary to perceptively observe the system, to collect the data corresponding to the model's input, and to perform an accurate analysis of the same data. The results and recommendations subsequent to the simulation are as legitimate as its modeling and inputs. In manufacturing systems build-to-order, that generates multiple products with identical characteristics and high levels of customization, the input analysis earns a vital role. On this article is proposed a methodology to deal with the variability inherent to systems, resorting to statistical inference methods: hypotheses testing. These methods are a vigorous tool on the analysis of data collected from the system. Furthermore, a case study based on a real manufacturing line will be presented, where the impact that the information inputted onto the model has in the simulation's results shall be analyzed, regarding the processing lead time. In addition, the presented case study provides evidence of the two foremost pitfalls, referred by Law, which ought to be avoided. The usage of the mean towards a statistical distribution misleads the system's analyst, whereas the normal distribution doesn't accurately represent the processing times. An adequate replication of the variability over the manufacturing processes from the real system, throughout the probability's distribution on an "off-line" simulation, comprises as a vital element to support decision making.

Keywords Modeling and simulation · Manufacturing lines · Production variability · Statistics

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_40,

40.1 Introduction

Simulation is characterized by the customary employment of mathematical and computational models that aid and support the decision-making process. The resort to these models is common when it's impossible or impracticable to perform experiences in the system itself [22]. The construction of a model enables not only to study a system without causing any disturbance on its regular behavior, but it also provides total freedom to test different ideas and solutions [8].

The high complexity verified in the systems currently considered, infers that its computation throughout analytical methods can be inefficient and may depend on an excessive simplification process, questioning the legitimacy of the model. The construction of a model must include an appropriate amount of detail, so that the output and consequent understanding from the model's outcomes may not differ from the potential insights and understanding engaged directly from the system. Consequently, despite simulation not being the only available tool concerning the study of models, it is quite frequently the method chosen to engage in its activity, as it allows the analysis of complex problems [2, 22]. Although its output is not precise, there are ways to deal with its imprecision, to quantify it or to reduce it. It is preferable to obtain an approximate answer to a correct problem than an exact solution to a wrong problem [8].

Ingalls [6] defines simulation as "the process of designing a dynamic model of an actual dynamic system for the purpose either of understanding the behavior of the system or of evaluating various strategies for the operation of the system". The user attempts to infer conjectures from the model to the real system via experimentation. Models are generally simplifications that comprise merely the scope and necessary amount of detail in order to satisfy the goals of the study [22]. By using software conceived to emulate systems' processes and characteristics over time, the model's inputs are numerically exercised and its linkage with outputs is verified, with the aim of determining estimates of the system's performance status.

Jahangirian et al. [7] perform a revision of the application of simulation techniques within industrial sectors, covering articles between 1997 and 2006 and concluding that discrete-event simulation (DES) is the dominant technique concerning simulation's applications over this sector. DES models tend to be suitable to detailed process analysis, resource management or queuing, being that the authors also verified several applications regarding operational management from its planning and production control, to process engineering, inventory management, project management or supply chain, over diversified areas of industry.

DES models have proved to be an excellent tool on the modeling, analysis, and improvement of the production systems' performance. The disclosure of accessible and user-friendly software contributes to the rapid increase of its applications [18].

The current simulation-based softwares available are impressive concerning its range capacity, program capability and sophistication, providing an incomparable support to the development, display and analysis of complex models. Its capacities are the convergence of more the half-century of evolution in software, hardware and simulation's investigation [20]. Swain performs a biannual survey [21] focused on DES based simulators, which according to the author are the most adequate to apply in management and operational sciences. Throughout the years the author has observed and incremental increase on the range and variety of simulators, which is reflected on the strength and robustness of the products, as well as the progressively growing sophistication of its users. To carry out such evolution, it has been important the contribution of aspects such as the improvements introduced on the analysis process, as well as the higher capability to obtain significant replications of a certain experience, which substantially increased the precision verified on statistical indicators, subsequent from the simulation, and the possibility to combine different scenarios. The recently available simulators are increasingly more precise when it comes to respond to problems and in providing solutions.

The optimization of processes and operations on manufacturing systems remains as an important sector on the segment of simulation, which is reflected on the innumerous products available and identified on the survey, concerning the manufacturing sector.

In order to successfully study simulation and attain its consequent validation, it's critical to follow a pre-defined approach that links the construction of the model to a reliable representation of the reality [10]. Skoogh et al. [18] refers that the majority of project's stages concerning this area interacts with the input and output data, being the management of this information the most frequent challenged identified in a simulation project. To this author, the data gathering, analysis and inputs into the simulation model are vital stages within a project.

Also to Biller and Gunes [3] and Kuhl et al. [9], the selection of a valid input is one of the main problems identified in the construction of stochastic models. The modeling of the input consists on the selection of the probability distributions that represent the random variables from the system [3], such as the registered periods of an equipment's failure, or the time between arrivals on a bank. The goal is not to obtain an exact input but an approximation that may capture the key features from each process.

In order to attain a successful simulation, Law [11] identifies two pitfalls to avoid, related with the model's input. The first concerns the frequent substitution of the probability's distribution by its mean, which according to the author may lead to utterly erroneous results, affecting the legitimacy of the outputs. Contrarily to the mean, probability's distributions introduce the variability that regularly occurs on the systems, having a significant effect concerning the traffic in queuing systems. Taking into consideration the distribution's utility in representing the sources of randomness of each system, the second pitfall referred by Law is the persistent utilization of the normal distribution on the model's inputs, being that it is actually rarely adequate to model diverse variations, such as service times, processing times or maintenance operations.

Thus, the choice of a probability's distribution has a large impact on simulation's results and, potentially, on the quality of the decisions taken based on such results. The inadequacy on the choice of the correct distribution affects the model's precision of results, sometimes drastically [2].

The problem in selecting the appropriate input worsens itself on *build-to-order* manufacturing systems, with low volume and high variability, which produce multiple products with high level of customization in each order, as it happens within organizations that produce electrical devises of higher dimensions. These characteristics introduce a great variability over operational processing times. The same operation can extend to for a few hours within a model, and for more than one shift on the next model.

To engage an off-line simulation of a manufacturing line of this kind it's necessary to carefully analyze the model's input to introduce, in order to characterize the variability existing on the system. Just as important as the use of adequate data on the model's construction is the attention to have in structuring the same data. According to Law [10], when several observations are performed to the same event, the homogeneity of data can be evaluated throughout statistical inference tests. If the set of data appear to be homogeneous, the data can be merged and the information can be used to the same purpose on the simulation's model. The manufacturing line's replication through simulation requires simplified models that, yet, can properly represent the reality.

40.2 Problem Statement

Prior to the application of the simulation, in order to promote comprehension, problem solving, process optimization and the study of alternative scenarios on a manufacturing system, it is necessary to gather and analyse the collected data to be able to construct a simple and reliable model. On this case study, it is intended to analyse the processing times of five operations engaged by a corporation that manufactures electrical devices, in order to further perform an off-line simulation, using the software *Arena*, from *Rockwell Automation*.

In organizations in which occurs the production of several products that follow the same manufacturing flow, and in order to properly structure the data and to simplify the simulation's model, it's necessary to verify if there are differences concerning the operation's lengths, according to the processed product. If no differences are verified, the data can be merged and used to represent the existing variability on the process throughout a probability's distribution. Otherwise, it's necessary to find, for each operation, a statistical distribution that can represent the corresponding product's processing time. On the other hand, this analysis enables the organization to determine in which operations are verified greater variability. Furthermore are following described the two main objectives of the presented case study:

1. To verify, throughout processing times, which models are significantly different from one another, in order to be separately modeled in each operation.
2. To adjust the processing times to the statistical distribution that best represents its behavior.

Finally, resorting software *Arena*, it will be examined the first pitfall referred by Law [2]: the frequent replacement of the probability's distribution by its mean. It will be compared the performance of the manufacturing line after introduction of the results brought by the analysis accomplished, with the performance of the same line using merely the mean of the processing times collected for each operation.

40.3 Methodology

In order to characterize the processes' variability over the production line, statistical inference methods are used to further represent it on simulation. One of its most useful applications is the hypothesis tests, whose objective is to verify the plausibility of a particular statement performed. According to Montgomery [13], several engineering tests or experiments involving decisions can be generated through these methods.

The presented hypothesis to be tested, designated Null hypothesis (H_o) must contain an equality which is considered to be truth until a statistical evidence proves it to be wrong. In that case, the alternative hypothesis (H_a), that should contain an inequality, becomes valid. It's essential to highlight that hypothesis are statements about populations or probability distributions studied, and not about samples. Montgomery [13] and Elisabeth Reis [16] developed profounder works concerning this topic.

Nowadays there's a wide variety of hypothesis tests, though in order to select the appropriate test, the type of data collected and purpose of the analysis must be considered for each situation [12]. The analysis of variability in this case-study, achieves the proposed objectives by means of diverse hypothesis tests. In Sect. 40.3.1, a methodology is introduced to perform the comparison of processing times for the diverse products through parametric or non-parametric tests, according to the normality of samples. In Sect. 40.3.2, a method is described for modeling the sources of system randomness through statistical distributions.

40.3.1 Data Structure

To attain a forthcoming characterization of processing times throughout statistical distributions, it's necessary to structure the available data, determining in which processes the operation's length significantly varies with the processed product.

Each set of times from an operation represents a population. In order to determine the population's behavior it's necessary to know its distribution and the value of each parameter. To do so, random samples of the population for each product are obtained, and it is performed a comparison between them, through parametric and non-parametric tests. The goal of this comparison is to verify if the samples can be considered as being resultant from the same population, i.e. if the processing times of a certain operation A don't differ according to the item produced X, Y, or Z.

Table 40.1 Hypothesis tests designated for the comparison of two or more independent samples

	Parametric tests		Non-parametric tests
2 Population	Mean	T-test	Mann-Whitney test
	Variance	F-test	
k Population comparison	Mean	Scheffe test	Kruskal-Wallis test
		HSD Tukey	
	Variance	Bartlett test	

On the majority of statistical procedures it is required the evaluation of normality assumption, being the parametric statistic one of those examples. When the assumption is disrupted, the interpretation and inference may not be trustworthy, or even valid [14].

Although many practitioners and simulation books use and state normal distribution, sources of randomness from manufacturing systems frequently discharge to follow this distribution [2]. If the population's distribution from which the samples were taken remains unknown, the first step to perform a statistical analysis consists in executing a normality test, in order to verify whether if the variable in study follows a normal distribution. In the case it does, the analysis may proceed by resourcing to parametric tests. In the case it doesn't, only the non-parametric tests are liable to be applied.

The cases of acceptance or rejection of the normality assumption have played a central role in many investigation sectors. Consequently, efforts in the creation, development and application of *goodness-of-fit* tests for normality, have been performed throughout the years, which resulted in a wide number of currently available tests and multiple comparisons concerning its power. This discussion currently aids the analyst in performing the adequate choice to each specific situation [17].

According to Razali et al. [15], the most common tests are Kolmogorov-Smirnov (KS), Anderson-Darling (AD), Lilliefors (LF) and Shapiro-Wilk (SW). These four are the foremost tests that are generally available on statistical softwares. Through the comparison of the results obtained over the studies endeavored by Refs. [14, 15, 17] it's possible to conclude that SW test is the most suitable and most consistent option in order to study the normality of the sample. The results obtained from the SW test will determine the application of the following hypothesis tests (Table 40.1).

While engaging in parametric tests, the objective is to study the differences between parameters, mean and variance, from different populations. It is considered that different samples are originated from the same population in case there are no significant differences between their means and variances. Depending on the parameter and number of samples (k) to study, it is selected the most adequate test. In addition, it is assumed that, in regard to comparison tests concerning the mean, the samples are taken from normally distributed populations with equal variances. This assumption primarily involves the execution of the variance comparison test, as shown in Fig. 40.1.

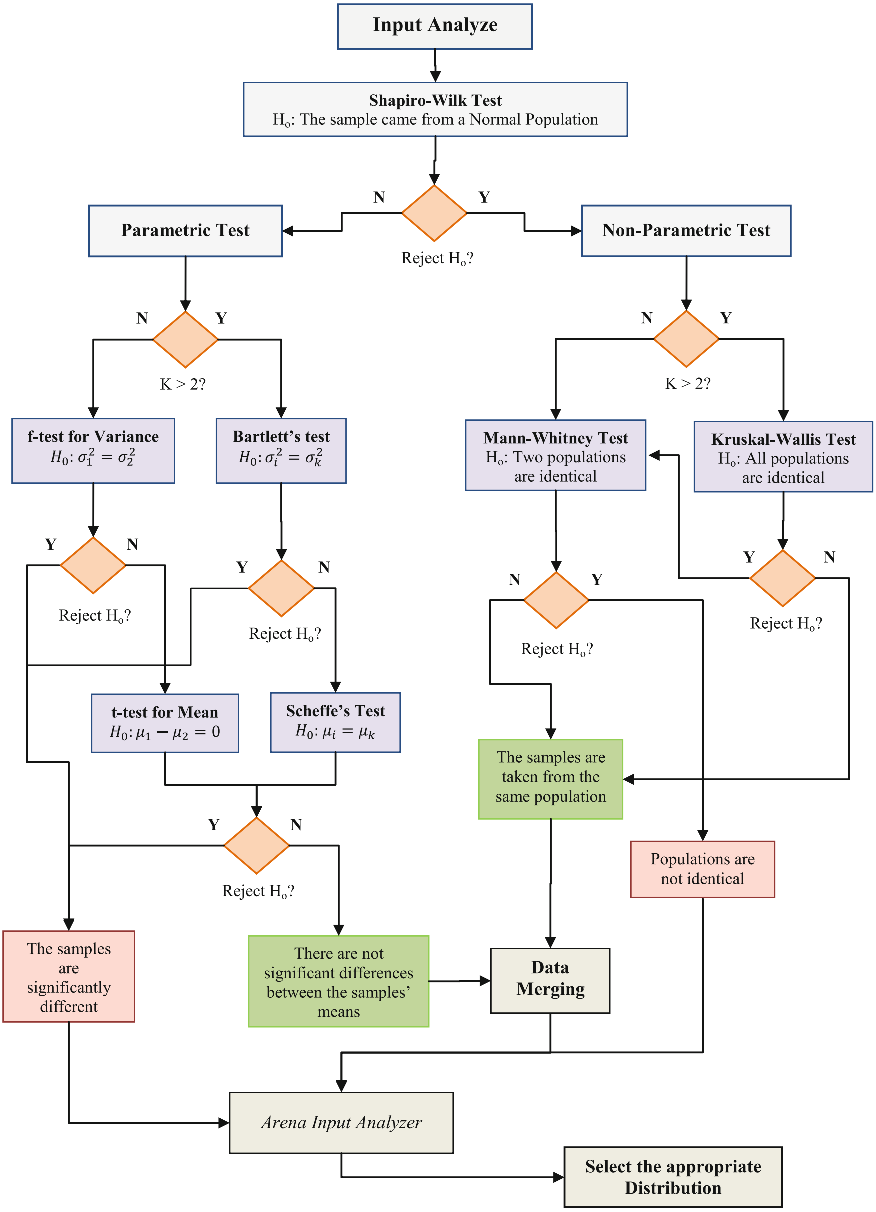

Fig. 40.1 Methodology map

The non-rejection of H_o, concerning these tests, forwards the process into the comparison of means; otherwise it's considered that there are significant differences over the samples' variance and, consequently, infers that the samples were withdrawn from different populations.

From the several tests entailed in comparing the means, the selection resided on the multiple comparison testes, in which the Tukey's HSD test and Scheffe's test are the most frequently used [16]. This tendency is related with the fact that ANOVA merely indicates whether if there are significant differences among analyzed groups, not specifying which group or which linkage between groups verify those differences.

Between multiple comparison tests, Reis [16] gives preference to Scheffe's test, due to its simplicity in the calculation associated, to its consistency in regard to its assumptions, and to allowing the usage of samples with different dimensions.

In the case the test confirms that the samples derive from populations with equivalent means, and knowing that they also possess corresponding variances, it's possible to merge the data and hence it's possible to consider that there are no significant differences between the means of processing times.

On the other hand, in the case that the means of the merged data are significantly different, the processing times of the corresponding models are separately shaped.

Non-parametric methods own its designation to the fact of the entities in study not being the parameters of a population and thus not being necessary to specify the distribution of the corresponding sample, and thus not having to comply with the normality assumption. These methods are generally less powerful and flexible than its homologous parametric methods and therefore, as long as the presuppositions from parametric methods are verified, they should be comprehended as a priority [12]. According to Montgomery and Runger [13] non-parametric tests are less efficient and need samples with larger dimensions in order to reach the same power than parametric methods. However, this difference is not resolutely severe and when the inherent distribution is not normally approximated, these methods are extremely useful.

In these kinds of tests are not performed comparisons in regard to means or variances, being that what's primarily assessed is whether if the shape of the distribution is the same for all samples. To perform a two population comparison test, Montgomery and Runger [13] and McCrum-Gardner [12] recommend the *Mann-Whitney* test, for it is considered to be the non-parametric alternative to t test for differences between means. Finally, in order to compare populations from k independent samples, it must be engaged *Kruskall-Wallis* test, which is a generalization for $k > 2$ samples from the *Mann-Whitney* test.

The rejection of H_o suggests that populations are not identical and it confirms that processing times are directly influenced by the processed model and, consequently, the data can't be merged over the next step. Otherwise, if H_o is not rejected, it means that it doesn't comprise statistical evidence, which infers that the processing times analyzed vary according to the product. Thus data will be merged.

40.3.2 Fit the Statistic Distribution

The assortment of a statistical distribution to a clutch of data can be performed empirically or throughout standard techniques of statistical inference. These techniques consist on the adjustment from several theoretical distributions to the available data, determining the distribution that delivers the closest approximation to the data. According to Law [11], in regard to the empirical approach, only the observed data interval can be generated in the model, which is problematic in case the samples are small. Since is established a theoretical distribution that properly represents the available data, it should be given preference to the statistical inference methods.

In the second part of the statistical analysis it is intended to select the distribution that most accurately represents each set of processing times. This distribution's selection process is currently an important tool for organizations to deal with risks and uncertainties existing among their processes. On the majority of cases, none of the adjusted distributions is precisely correct and thus the goal is to determine the distribution that is sufficiently precise and adequate to the model's purposes [11].

When there is available data, both Biller and Gunes [3] and Law [11] designate three stages to specify a theoretical distribution that may represent the data:

1. Select one or more candidate families of distributions, based on the process's physical characteristics and graphical examination of the data;
2. Estimation of parameters;
3. Check the *goodness-of-fit* via tests and graphical analysis.

According to Kelton et al. [8], the selection of the probability's distribution to apply also depends on the type of data in study. In order to study "Task times", a positive continuous variable, the author indicates as most adequate the distributions Erlang, Gamma, Weibull and Lognormal.

Developing these procedures can be a difficult task, expending a great deal of time and with a will to fall in errors and faults [2], along with the fact that in many of these cases it's complicated to adjust the observed data to less common statistical distributions. For such reasons, the majority of the applications are performed throughout softwares that automatically determine the most accurate distribution adjusted with the data provided. Two frequently used programs that fit this purpose are *Arena Input Analyzer* and *Expert Fit* [4].

Due to the acquaintance with the software, and due to its capabilities to serve the purpose of the present work, the extant case-study was endeavored on the software *Arena, Rockwell Automation*, in order to simulate a production line. Consequently it was resorted the module *Input Analyzer* in order to determine the distribution that most accurately represents the inputted data and its parameters. With the function *"Fit Al"*, the distributions are classified according to its relevancy, based on the values of the corresponding square errors. The selected distribution is then placed into the proper format for direct input in Arena Software.

The module *Input Analyzer*, integrated in Arena software package, also allows the execution of two *goodness-of-fit* tests: *Chi-Square* and *Kolmogorov-Smirnov*. Since the distribution inherent to the studied population remains unknown, the goal of these tests is to study the hypotheses that a certain distribution will fulfill as population model [13].

On the present literature review are studied several *goodness-of-fit* tests, their resultant evolution and numerous comparisons [1, 5, 19, 23]. According to

Kelton et al. [8], there are no conventional and universally established approaches to determine a certain distribution, as for different statistical tests may classify distributions according to dissimilar degrees of relevancy.

The majority of softwares that apply these methods enclose *Chi-Square, Kolmogorov-Smirnov* (KS) and *Anderson-Darling* (AD). Fischer and Kamps [5] compared the power of five *goodness-of-fit* tests and concluded that when statistical values (distribution parameters) differ, the test power differs and consequently the selection of the most adequate test differs along with the results. However, Fisher also states that, in case that only one test is recommended, probably the AD test is the best choice of selection, for it is the most powerful application in several different situations and always the most competitive on situations where it is not the foremost selection. A disadvantage from *Input Analyzer* points out the fact that it doesn't contain the AD test.

40.4 Application/Case Study

The simulation engaged in this study focuses on a production line in which are produced three electrical devices X, Y and Z, with similar characteristics. All three products add up to exactly the same manufacturing flow composed by 5 processes—A, B, C, D and E. The available data employed to analyse the input's variability was collected from a computerized data source from within the company where the results where attained, and comprise the processing times from five years of historical data. After the assembling and validation of the data along with the designated organization, it was initiated an analysis to formulate a set of solutions for both of the problems mentioned in (1) and (2). In order to execute the multiple hypotheses testing, it was used the SPSS software, because it embraces all statistical procedures to apply.

The efforts were initiated with *Shapiro-Wilk* test, being rejected H_o for all samples as observed on Table 40.2, and being able to conclude that no set of processing times belongs to a normally distributed population. Consequently, the effecting of parametric tests was not carried out.

Due to the non-normality of the samples and intending to compare three sets of processing times ($k = 3$), the *Kruskal–Wallis* test was performed. Results revealed that in two processes (B and E) it is not rejected the hypotheses of being identical the populations from which the samples are obtained. Consequently, in these two processes, the length of operations doesn't vary depending on the product, thus the samples are considered to be homogeneous and its data is merged.

When H_o is rejected, it's performed *Mann-Whitney* test to compare each couple of samples, aiming to verify if the variability displayed in the process is particularly caused by any of the products. On process A the distributions of the three samples are significantly different, concluding that the processed item is determinative to the length of the operation. Both in processes C and D, the two products' processing times are homogeneous, being these set of data also merged.

Table 40.2 Results of the statistical tests

	Process A	Process B	Process C		Process D		Process E
Statistical test	X Y Z	X Y Z	X Y	Z	X	Y Z	X Y Z
Shapiro-Wilk	Reject H_a	Reject H_a	Reject H_a		Reject H_a		Reject H_a
Kruskal-Wallis	Reject H_a	Failure to Reject H_a	Reject H_a		Reject H_a		Failure to Reject H_a
Mann-Whitney	Reject H_a	NA	Failure to Reject H_a	–	–	Failure to Reject H_a	NA
	–	Data merging	Data merging	–	–	Data merging	Data merging

Table 40.3 Results from the input analyzer

Production line	Products	Input probability distribution
Process A	X	$4 + ERLA(16.8, 3)$
	Y	$4 + WEIB(37.3, 1.72)$
	Z	$1 + WEIB(22.3, 2.19)$
Process B	X, Y, Z	$4 + WEIB(16.7, 1.8)$
Process C	X, Y	$2 + WEIB(19, 1.48)$
	Z	$1 + LOGN(13, 17.4)$
Process D	X	$10 + WEIB(29.6, 2.22)$
	Y, Z	$10 + GAMM(11.2, 3.26)$
Process E	X, Y, Z	$2 + GAMM(3.34, 5.38)$

On the following stage, each set of data was introduced in *Input Analizer*, which selected the adequate distributed through the less squared error criteria. Throughout *Kolmogorov-Smirnov* test it was able to confirm that the selected distribution is appropriate as a population's model.

The results of these *goodness-of-fit* tests are presented in the shape of p-values, which is the largest value of the type-I error probability that allows the distribution to fit the data. The higher the p-value, the better is the fit. On this study it was rejected H_o to values of p-value smaller or equal to the specified significance: 0.05. The results revealed in *Input Analizer* are shown on Table 40.3.

The analysis performed supports that the information inputted on the model may represent the variability that truthfully exists amongst the manufacturing line. The importance verified on the structuring, as well as the modelling of the data through a probability distribution that represents the system's random variables, are represented on Table 40.4, where can be observed the results of two simulations on the manufacturing line. In Table 40.4 is displayed a comparison between the overall time that products X, Y and Z remain in the system, when are applied the results from statistical analysis (Case I), and when it is inputted the mean of the collected samples in each process from the simulation's model (Case II). It can be verified that in Case II all products remain less time within the manufacturing line. In addition, the mean

Table 40.4 Comparison between processing lead times using sample's mean and using a probability's distribution

Product	Total time in the production line (h)		Percentage of time increased using distributions
	Case I: *a*	Case II: *b*	
X	245.25	217.64	12.69
Y	271.8	220.5	23.27
Z	241.59	218.5	10.57
Total	255.96	219.22	16.76

a: Probability Distribution inputs; *b*: Sample's mean inputs

from the processing lead times is lesser 16,76 % on Case I. This is due to the fact that the normal variations existing among the processes of a manufacturing line are not accounted, misleading the production manager. On the other hand, with an adequate input of the variability from processing times in Case II, the three products take longer in 10 % of the time. In contrast, it can be verified that product Y is the one taking longer to be manufactured. This different is only noticeable after an analysis of the input carried on this case-study.

40.5 Conclusions

The presented methodology, intended to characterize the collected data from a manufacturing line with a high degree of variability, enabled to conclude that the two pitfalls referred by Law substantially affect simulation's results. On the one hand, despite being heavily applied, the normal distribution is not the most appropriate distribution to model many datasets, such as processing times. Throughout *Shapiro-Wilk* test it was confirmed that any sample was correctly described by this distribution. On the other hand, several practitioners frequently replace the usage of a probability's distribution by the value of the sample's mean. Hence, it was possible to conclude that this replacement misleads the analyst because the variability prevailing in the system is not inputted on the model, altering results and thus conducting the manager or person in charge into the risk of carrying decisions that may harm the corresponding organization. To refer that in the present work was used the KS test to engage in the *goodness-of-fit*, due to the fact of being available in ARENA's *Input Analyzer*. However, several studies point out to a greater power concerning Anderson-Darling's test, being this the most adequate choice. The recourse to softwares that include this test, such as *Experfit*, ought to be considered.

Equally important as a correct selection of the distribution that truthfully represents the collected data from the system, is a careful information structuring. Through a sequence of statistical inference tests it was verified that it prevails significant differences regarding the product's processing times, which should be addressed. In addition to a correct input of the information into the model, this analysis enables the organization to verify in which processes comprise higher sources of variation.

The use of statistical methods on the modelling and analysis of the simulation's input is vital, in order to acquire a reliable representation from the system and consequently to attain a high credibility and legitimacy of the simulation's results.

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Chapter 41
Corporate Governance and the Use of Raised Capital: Evidence from China's Growth Enterprise Market

Yiguang Li, Dongyu Bai and Yang Rong

Abstract In this paper, we discussed the relationship between corporate governance and the use of raised capital using the data from China's growth enterprise market (GEM). Based on the data manually collected from the annual report 2012 of 355 GEM-listed companies, we found that some companies changed their promised projects of raised capital and some companies had serious over-investment behavior in using of IPO over-financing. We also found that good corporate governance mechanisms can effectively alleviate the problem of changes in promised projects. CEO duality and independent directors can inhibit the changes of promised projects, while the governance of the largest shareholder is functioning. The incentive compensation for the manager can effectively alleviate the over-investment problem. We also found that over-financing makes contribution to the changes of promised projects. In addition, we found that the use of over-financing is concerning the optimizing of companies' balance sheet, which also has the satisfaction effects after a short expansion.

Keywords Corporate governance · IPO over-financing · Agency problem

41.1 Introduction

In October 2009, China went a step further in the construction of multi-level capital market system, which was the introduction of China's NASDAQ-Growth Enterprise Market (GEM). GEM has been chased by social funds since then, which leads to

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_41,

ultra-high price-earnings ratio and ultra-high over-financing ratio.[1] As of October 2012,[2] 355 high-growth companies listed on GEM. The average price-earnings ratio of them is 69.62. The number of over-financed companies is 347, within which 239 companies have over-financing ratio larger than 100 %, while 155 % on average.

However, there are still problems in GEM. Under the approval IPO mechanism, listed companies are inclined to excessively whitewash their financial statements, regulators always act as the "hidden guarantors" for them, the abuse of power and other problems persist. With low proportion of institutional investors, herding problem is obvious. Many of the GEM's original shareholders tend to draw cash from the listed companies rather than continuously operate them. Shortly after the listed companies have raised capitals from GEM, they changed the promised projects. Some companies blindly chase hot spot of markets, purchase land and office buildings, and do not have long-term development strategy. These problems, especially the problems in using raised capital are concerned by our paper.

We argues that the abuse of raised capital not only caused by increasing of free cash flow, but more affected by the structure of cooperate governance, such as large shareholder governance, CEO duality, independent director's supervision and incentive compensation for managers.

In this paper we collected the data of the use of raised capital from 355 listed companies on GEM, which include the data of changes in promised projects and the data of investments of over-financing. We have drawn some meaningful conclusions by analyzing the details of investments, and by testing the relationship between the investments and corporate governance factors. We make a number of theoretical contributions to the literature in this paper:

Firstly, through the studies in the use of raised capital by the data of GEM listed companies, we found that over-financing has a significant positive effect on the changes of promised projects, which is consistent with the conclusion of Jensen [15]—that excess IPO proceeds can lead to distortion of the company's capital allocation.

Secondly, by studying the relationship between the changes of promised projects and corporate governance, we have proved that appropriate corporate governance arrangements, such as increasing the proportion of independent directors and CEO duality, could guarantee the implementation of the promised projects. This conclusion is not only helpful for the company itself in improving the efficiency in using the raised capital in way of optimizing the corporate governance, but also constructive for regulators in protecting the interests of investors.

Finally, we analyzed the relationship between investment of over-financing and corporate governance, which has verified the importance of incentive compensation for managements. In addition, we found that there are a significant positive correlation between investment of over-financing and debt-asset ratio, but no significant

[1] Over-financing ratio is the proportion of over-financing to planed financing.

[2] IPO of China's stock market has been suspended since October 2012, and will be restarted in January of 2014. Until we published this paper, the number of companies listed on GEM is still 355.

relationship between over-financing and performance. We also found that there is a satiation effect in investment of over-financing, which means that the majority of over-financing is still idle after a brief expansion of investment.

The remainder of this paper is organized as follows. In Sect. 41.2, we outline our theoretical analysis and develop our hypotheses. Section 41.3 presents the research design and Sect. 41.4 provides the test results and empirical analysis. Additional checks are discussed in Sect. 41.5. Section 41.6 concludes the paper.

41.2 Theoretical Analysis and Hypotheses

The aims of the GEM are to finance for development of high-growth enterprises, to provide the exit for venture capitals. However, with emergence of high over-financing ratio, a lot of free cash flow are created, which have increased probability of agency problem.

In mature capital markets such as the NASDAQ, structure of investors' is more reasonable; listed companies have a relatively sound regulatory system; valuation of company is more accurate, so the over-financing phenomenon is not obvious. Most of the listed companies use the raised capital according to their prospectus. If a listed company changes its promised projects soon after IPO, or the disclosure is not timely, it will be subject to rigorous investigation and is likely to suffer the penalty of capital markets. Recent literature is mainly about over investment, inefficient investment, abuse of free cash flow, researches of use of raised capital and its influencing factors are quite rare.

After over financing from the selling market, listed company abundant in of free cash flow is inclined to invest inefficiently. Jensen [15] and Stulz [22] found that when corporate governance mechanisms are inadequate, managers will take advantage of the company's internal free cash flow and over invest in the projects which generate their private benefits which may be conflict with the interests of shareholders. As corporate governance mechanisms are inadequate, agency problem occurs, which leads to the low efficiency since managers invest excessively. When a large number of idle cash exists, managers might invest funds in empire building, perquisite consumption, diversifying acquisitions, and subsidizing poorly performing divisions.

Good corporate governance is the key which determines efficiency of uses of raised capital. Good corporate governance mechanism can effectively inhibit the manager's pursuit of private benefits. Harford et al. [14] found the poorer corporate governance of company has, the lower the level of cash reserves are, in which certain cash abuse exists.

Thus, we selected four representative factors named share of the largest shareholder, proportion of independent directors, CEO duality, and incentive compensation for managements to study their effects on changes of promised projects and the use of IPO over-financing.

Firstly, Grossman and Hart [13] pointed out that when equity is highly fragmented, small shareholders don't have enough incentive to monitor managers, which results in insufficient supply of supervision. The major shareholder could use their voting rights to make sure the decisions are efficient. However, Shleifer and Vishny [21] also proposed that conflicts of interest between large shareholders and small shareholders in the ownership concentration leads to new agency cost, named "tunneling effect". Albuquerue and Wang [2] found that in the case of inadequate protection for investors, major shareholder tends to over invest, because private benefits of control are positively correlated with the size a company. Bai et al. [3] proved that the proportion of the largest shareholder's share is correlated negatively with value of company, and equity balance has a positive impact on value of company. Of course, there are also studies which showed that the governance effects of major shareholder are not significant. Above all, there is not a consensus in current researches on the impact of major shareholder. However, as to verify the impact of the largest shareholder on uses of raised capital, we propose the first hypothesis:

Hypothesis 1 The higher the proportion of the largest shareholder's shares is, the easier the change of promised projects is, and the more excessive the over-financing is used.

Secondly, supervisory role of independent directors in the listed companies has been confirmed by most studies [7, 11, 18], as Weisbach found, the independent directors can use their professional backgrounds and social relations to improve governance of the companies. Wang et al. [23] found that the proportion of independent directors and corporate performance are significantly positive correlated. They also found that the monitoring function of independent directors is decreased by governance of major shareholder. Although Mace [19] offered reverse examples that independent directors seldom question behaviors of managements publicly, this makes them "rubber stamp". Independent directors concerning their reputation would still act the supervising roles vigorously, which alleviate the agency problem. In the research concerning the role played by independent directors on over-investment, Richardson [20] found that independent directors can reduce the possibility of over-investment, using the data of United States. Based on the analysis above, we proposed the second hypothesis:

Hypothesis 2 The higher the proportion of independent directors is, the easier the change of promised projects is, and the more excessive the over-financing is used.

Thirdly, the two main theories referring to CEO duality are the agency theory and the modern stewardship theory. Based on the agency theory, Jensen and Murphy [16] found that CEO duality reduces supervision of board, which leads to excessive expansion of general managers' power, then leads to autocratic decision and over investment. Even for now, the practice of splitting duality roles of CEO and Chairman within pubic corporations is still a common practice within the USA [1]. However, Donaldson [10] had an alternative explanation that the general managers could run the company diligently for their dignity, beliefs, and pursuit of intrinsic satisfaction of job. Therefore, the primary issue is not to supervise the managers, but to motivate them to act dutifully and bravely when company is facing a new market environment. CEO duality can improve the innovation space of executive team, and help them vigorously responding to the external environment, especially for a growing company [6]. Positive correlation between CEO duality and performance were proven by study of Cannella and Lubatkin [8]. Unlike main board of the stock market, the listed company in GEM should enforce continuous innovation to gain sustained growth, which is the biggest selling point of GEM. In order to inspire innovation, a company needs to break through some traditional constraints, and it is necessary to give general managers adequate management right. Therefore, the major shareholders of GEM listed companies are willing to apply CEO duality to avoid undiligent external managers, and to keep the traditional strengths. Based on the analysis above, we proposed the third hypothesis:

Hypothesis 3 CEO duality can effectively alleviates the change of promised projects and the excessive use the over-financing.

Fourthly, some researchers confirmed that incentive compensation for management, size of a company, and performance of it are positively correlated with one another [4, 9, 17]. Some studies found that incentive compensation and size of company are positively correlated [25]. While recent studies have confirmed that not only big companies are willing to pay more salary to managers, growth companies are also willing to pay higher salaries to attract high-level managers. Gabaix and Landier [12] suggested that the hand pushing the pay of executive is the stronger demand for qualified professional managers. For GEM listed companies, managers should be motivated by higher compensations, to ensure that they are diligent in changing era. The fourth assumption is as following.

Hypothesis 4 The less the incentive compensation managers receive, the easier the change of promised investments projects is, and the more excessive the over-financing is used.

41.3 Research Design

41.3.1 Sample Selection and Data Sources

As the IPO of China stock market suspended in November 2012, which is expected to restart in January 2014, we only have the data of 355 GEM listed companies so far. According to the "Securities Law" and the China Securities Regulatory Commission Announcement (2012) No. 44, the GEM listed companies should disclose the utilization of raised capital, in which the change of promised projects and investment of over-financing are disclosed in details. We have collected these data from annual reports 2012. Annual reports were downloaded from http://www.cninfo.com.cn/. Financial and corporate governance data are obtained from the China Stock Market and Accounting Research (CSMAR) database.

41.3.2 Description of Uses of Raised Capital in Promised Projects and New Projects

We divided the promised projects into 5 parts—the productive construction projects, the construction projects of R&D center, the construction projects of marketing network, the supplement of liquidity and the M&A. The changes referred in this paper are defined that the promised projects are stopped or are replaced by other new projects. If the promised projects are finished with surpluses, and the surpluses are invested in supplement of liquidity, we do not count the changes.

IPO over-financing should be used in the main business and related projects, which are regulated by the "Listed Company Supervision Guideline No. 2—the regulatory requirements for the use of raised capital of listed companies" As a guideline, the over-financing are mainly invested in 7 types—the productive construction projects, the construction projects of R&D center, the construction projects of marketing network, the supplement of liquidity, the M&A, the loan repayment, and the purchase of land and office space. The idle over-financing is saved in a monitored bank account.

41.3.3 Model Specification and Variable Definitions

We take the change of promised projects and the investment of over-financing as two dependent variables, and establish two models—a logistic regression model and a linear regression model. We take the proportion of the largest shareholder, the proportion of independent directors, the CEO duality and the incentive compensation for management as explanatory variables. Then we take total asset, debt-asset ratio, ROE and over-financing ratio as control variables. The definitions of the main variables are presented in Table 41.1. The models are as follows:

Model 1:

$$\text{Change} = \alpha_0 + \alpha_1\text{Stock} + \alpha_2\text{Inde} + \alpha_3\text{Dual} + \alpha_4\text{LnPay} + \alpha_5\text{LnAsset} + \alpha_6\text{DAR} + \alpha_7\text{ROE} + \alpha_8\text{OF} + \varepsilon.$$

Model 2:

$$\text{OFI} = \alpha_0 + \alpha_1\text{Stock} + \alpha_2\text{Inde} + \alpha_3\text{Dual} + \alpha_4\text{LnPay} + \alpha_5\text{LnAsset} + \alpha_6\text{DAR} + \alpha_7\text{ROE} + \alpha_8\text{OF} + \varepsilon.$$

41.4 Empirical Results

41.4.1 Descriptive Statistics

Table 41.2 shows the descriptive statistics results. We can see that 78 companies changed their promised projects, which take 21.97 % of 355 companies; average ratio of investment of over-financing is 53.59 %, with a median of 51.43 %, indicating that

Table 41.1 Definitions of variables

	Variable	Symbol	Definition
Dependent variables	Change of promised projects	Change	Dummy variable equal to 1 for change happened and 0 otherwise
	Investment of over-financing	OFI	The proportion of investment of over-financing
Explanatory variables	Proportion of the largest shareholder	Stock	Number of stock of the largest shareholder/Number of total stock
	Proportion of independent directors	Inde	Number of independent directors/Number of member of the board of directors
	CEO duality	Dual	Dummy variable equal to 1 for CEO duality and 0 otherwise
	Incentive compensation for management	LnPay	Natural logarithm of maximum amount of top three executives' compensation
Control variables	Total asset	LnAsset	Natural logarithm of total asset
	Debt-asset ratio	DAR	Total debt/Total asset
	Return on equity	ROE	Rate of return on common stockholders' equity
	Over-financing ratio	OF	Proportion of over-financing to planed financing

Table 41.2 Descriptive statistics

Variables	Mean	Median	SD	Min	Max	Total	N
Change	0.2197	0.00	0.4146	0.00	1.00	78	355
OFI	0.5359	0.5143	0.2996	0.00	1.00	–	323
Stock	0.3392	0.3143	0.1276	0.0877	0.6887	–	355
Inde	0.3750	0.3333	0.0539	0.25	0.60	–	355
Dual	0.4676	0	0.4997	0.00	1.00	166	355
LnPay	1.39E+06	1.16E+06	8.64E+05	3.06E+05	7.71E+06	–	355
LnAsset	1.24E+09	9.71E+08	8.35E+08	3.08E+08	6.31E+09	–	355
DAR	0.2019	0.1739	0.1347	0.01	0.76	–	355
ROE	0.0705	0.0749	0.0681	−0.73	0.31	–	355
OF	1.5499	1.3523	1.0750	−0.26	7.38	–	355

more than half of the companies have more than half of the over-financing used; average proportion of the largest shareholder is as high as 31.94 %, indicating that the equity balance degree of the companies is very low; 166 companies have chosen CEO duality, accounting for 46.76 % of the total number, indicating a higher degree of control of major shareholders.

Table 41.3 Regression results of corporate governance and changes of promised projects

	Model 1–1	Model 1–2	Model 1–3	Model 1–4	Model 1–5
Stock	−0.006				−0.003
	(0.567)				(0.796)
Inde		−4.374			−4.196
		(0.103)			(0.125)
Dual			−0.496*		−0.498*
			(0.064)		(0.068)
LnPay				−0.295	−0.391
				(0.277)	(0.159)
LnAsset	0.203	0.143	0.167	0.296	0.233
	(0.491)	(0.633)	(0.575)	(0.335)	(0.459)
DAR	0.163	0.172	0.263	0.027	0.123
	(0.882)	(0.876)	(0.812)	(0.981)	(0.913)
ROE	−2.738	−2.879	−2.571	−2.507	−2.526
	(0.139)	(0.119)	(0.169)	(0.173)	(0.178)
OF	0.205	0.219	0.226	0.217	0.236*
	(0.140)	(0.117)	(0.109)	(0.119)	(0.098)
Cons	−5.480	−2.816	−4.768	−3.500	0.971
	(0.354)	(0.649)	(0.423)	(0.575)	(0.884)
Nagelkerke R squre	0.039	0.050	0.052	0.043	0.071
N	355	355	355	355	355

*Significant at the 10 % level

41.4.2 Multivariate Regression Analysis

According to the first logistic regression model established, Table 41.3 shows the tests how corporate governance impacts the change of promised projects.

The results of model 1–1 and model 1–5 show that the largest shareholder doesn't significantly impact the change of the promised projects. As a possible explanation, it is considered that the GEM listed companies have both the positive monitoring and the negative over control effect by the largest shareholder, so they could do both good and harm to companies. Therefore we can't distinguish the mixed effect of it. H1 is not obvious.

The results of model 1–2 and model 1–5 show that independent directors can alleviate the change of promised projects. It can be explained by the supervision function of independent directors, especially when the listed companies are facing greater environmental fluctuations [24], they would inhibit the irrational impulse of listed companies in investing [20]. So the results support the Hypothesis 2.

The results of model 1–3 and model 1–5 show that CEO duality has significant effects in inhibiting the change of promised projects, which proves the modern stewardship theory of Donaldson [10]. Most of GEM-listed companies come from private enterprises, so most of them are holed by a major shareholder. The entrepreneurs are

Table 41.4 Regression results of corporate governance and investment of over-financing

	Model 2–1	Model 2–2	Model 2–3	Model 2–4	Model 2–5
Stock	$8.960E-7$				0.00
	(0.999)				(0.822)
Inde		−0.068			−0.102
		(0.802)			(0.709)
Dual			0.018		0.013
			(0.537)		(0.654)
LnPay				−0.063**	−0.063**
				(0.037)	(0.040)
LnAsset	0.043	0.042	0.045	0.065*	0.064*
	(0.202)	(0.214)	(0.184)	(0.065)	(0.068)
DAR	0.928***	0.928***	0.923***	0.900***	0.896***
	(.000)	(0.00)	(0.000)	(0.000)	(0.000)
ROE	−0.469**	−0.472**	−0.471**	−0.422**	−0.429**
	(.029)	(0.029)	(0.029)	(0.049)	(0.047)
OF	−0.025	−0.025	−0.025	−0.025	−0.025
	(0.145)	(0.148)	(0.138)	(0.137)	(0.137)
Cons	−0.477	−0.432	−0.524	−0.043	−0.046
	(0.479)	(0.534)	(0.438)	(0.951)	(0.951)
R squre	0.239	0.239	0.240	0.249	0.250
N	323	323	323	323	323

*Significant at the 10 % level
**Significant at the 5 % level
***Significant at the 1 % level

willing to operate the companies by way of CEO duality, in order to keep the original way of doing business which has been proved effective. The largest shareholder who chooses CEO duality is likely to keep their promises in prospectus. Above all the results support the Hypothesis 3.

The results of model 1–4 and model 1–5 show that incentive compensation for management has weak inhibiting effects on the change of promised projects, however, the test results are not significant. It can be explained as follows: the change of promised projects contributes less to the expansion of a company, so managers' salary can't be increased by changing, as emphasized by Bebchuk and Grinstein [5]. In turn, the effect of incentive compensation to change of promised projects is weak. So the results don't support the Hypothesis 4.

In addition, results from the logistic regression can also draw an important conclusion that the over-financing has a positive effect on the change of promised projects, which are consistent with the theory of free cash flow concluded by Jensen [15]. If a company has got excessive funds, the managers tend to over invest for their own interests. One of the ways to gain the personal interests is to change the projects.

According to the second linear regression model established, we can draw a few interesting conclusion from Table 41.4.

First of all, the effects of the governance of the largest shareholder, the supervision of independent directors and the CEO duality is not significant, which may indicate the failure of them in the use of over-financing. However, the incentive compensation is strongly significant in using over-financing (e.g. model 2–4 and model 2–5s). It can be explained that when the incentive compensation is insufficient, managers are inclined to invest for the purpose of rapid expansion, which leads to the increase of their own benefits.

From Table 41.4, we can also see that larger listed companies invest more, which means that they have greater expansion of industrial chain, so they can expand faster by way of merging the companies from upstream or downstream. Therefore, the over-financing of larger company will be used faster than the others.

In addition, the results of Table 41.4 show a significant positive relationship between debt-asset ratio and proportion of invested over-financing, which can be explained like this: parts of over-financing were used in supplements of liquidity and repayments of bank loans, which have the effect of optimizing the balance sheet. There also is a significant negative correlation between firm performance and proportion of investment, which can be explained as that the investment decreased the ROE or some companies have the impulsion in investing with the aim of promoting performance.

41.5 Robustness Tests

The data in this paper are collected from annual reports 2012 of GEM listed companies. Some companies have just listed and don't have enough time to change their promised projects or spend their over-financing. So the regression of whole samples may be biased, which would affect the significance of the models. Therefore, we removed 74 samples of GEM companies listed in 2012, and repeated our tests by the samples of the rest 281 listed companies.

By contrasting new regression results with the formers, we can see that most of our former results are robust. The significance of ROE decreased in model 2#, we argue that this may indicate a long-term relationship between financial performance and the use of over-financing. The negative relationship between over-financing ratio and the proportion of investment is more significant, which means that listed companies with high over-financing ratio do not spend all the raised capital in the short run. After a short expansion of investment, there is a satiation effect of over-financing investment.

41.6 Conclusions and Implications

In this paper, we studied the relationship between corporate governance and the use of raised capital using the cross-sectional data (2012) of 355 GEM listed companies. The major findings are as follows (Table 41.5).

Table 41.5 Robustness tests

	Stock	Inde	Dual	LnPay	LnAsset	DAR	ROE	OF	Cons	R squre	N
Model	−0.004	−4.351	−0.473*	−0.395	−0.011	0.254	−1.63	0.211*	6.365	0.055	281
1#	(0.732)	(0.122)	(0.095)	(0.175)	(0.974)	(0.828)	(0.368)	(0.073)	(0.368)		
Model	−0.001	−0.145	0.026	−0.07**	0.044	0.899***	−0.185	−0.039**	0.587	0.27	269
2#	(0.646)	(0.601)	(0.393)	(0.027)	(0.232)	(0.000)	(0.378)	(0.030)	(0.441)		

*Significant at the 10 % level
**Significant at the 5 % level
***Significant at the 1 % level

Firstly, changes of the promised project are positively affected by the ratio of over-financing, which is consistent with the conclusion of Jensen [15]—that excess IPO proceeds lead to distortion of the company's capital allocation.

Secondly, good corporate governance mechanisms can effectively alleviate the abuse of raised capital. Although the double tendencies of the largest shareholder lead to inconspicuous governance, the supervision of independent directors and the CEO duality are still functioning in inhibiting the changes of promised projects. In the case of strong external competition, the independent directors and the CEO as general manager would play active oversight roles in corporate governance.

Thirdly, incentive compensation cannot effectively inhibit the changes of promised projects, which can be explained as follows: the change of promised projects contribute less to the expansion of a company, so it can't increase managers' salary ether. At the same time, incentive compensation has significant impact on the investment of over-financing, which means that a company can raise the compensation for managers to alleviate the over-investment problem of over-financing.

In addition to these main conclusions the paper also proved that GEM listed companies use over-financing to optimize their balance sheet. However, there is no significant relationship between the performance of the company and the investment of over-financing. At last, we found the satiation effect in investing of over-financing, which means after a brief expansion of investment projects, the majority of raised capital is in idle.

Of course, the article also has the following limitations. First, we did not classify the investment of over-finance by good or bad decisions according to the NPV standard, which may lead to insufficient research on the over investment problem; secondly, we use the four factors of corporate governance to measure the level of it, which may be not enough while concerning that these factors could affect one another; thirdly, we selected cross-section data of 2012 to study the dynamic relationship between corporate governance and investment, which may be biased in lack of comparison of different periods. We will discuss these three points further in future studies.

Acknowledgments The authors thank the anonymous referees and editor for their constructive suggestions. Any errors are the sole responsibility of the authors. We are grateful for the support from the National Philosophy and Social Sciences Funding program (Grant No. 09AZD046).

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Chapter 42
An Empirical Study on the Impact of Person–Organization Fit on Organizational Effectiveness

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Abstract As the emerging theory of western organizational behavior (OB), Person–Organization fit (P–O fit) recently has been a hot topic among scholars both at home and abroad, especially the effect of P–O fit on the organization. So this paper intends to explore P–O fit and organizational effectiveness literatures to investigate the interrelationships between them. We put forward the fit of fulfilling degree of employee-organization's values as a measuring index for P–O fit and analyze how it impacts on organizational effectiveness through establishing a research model. Testify fit indices of the model by SEM method indicate that P–O fit is positively related to organizational effectiveness.

Keywords P–O fit · Organizational effectiveness · The fulfilling degree of values · SEM

42.1 Introduction

Since the 1990s, Western enterprises, under the pressure of changing environment and intense competition, were faced with frequent changes and high rate of brain drain. Therefore, how to attract, select and retain high-quality employees, how to maintain a good relationship between enterprise and employees, and how those issues influence organizational management have become a hot topic among managers. In this context, person–organization fit has been the emerging theory in OB (Organizational Behavior) in the western academic circles, which mainly discusses how to realize the matching between employees and the organization and the result of

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_42,

Person–Organization fit (P–O fit). As for the domestic enterprises, due to the dynamic developing circumstances, P–O fit has been an important issue of human resource management, which has drawn the great attention of management layer.

Within the existing studies, there are three categories for P–O fit can be classified by Kristof:

1. Either individuals or organizations could satisfy the counterpart's needs, that is, the complementary matching;
2. Both individuals and organizations have similar characteristic in some respects, that is, the consistent matching;
3. Both two cases occur [15].

In some literature, P–O fit has typically been conceptualized as the degree of congruence between employee and organizational beliefs, norms, values [6], and goals [16]. A number of studies abroad have proved that P–O fit could bring some positive impact on employees' job satisfaction [10, 25, 26], prosocial behavior [19, 21] work performance [1, 5] and generating positive subjective experiences [2]. Furthermore, P–O fit affects employee engagement and leads to variance in organizational commitment [4]. That is to say, employee engagement goes beyond the traditional nation of job satisfaction, is more important and vital to affect the organizational effectiveness. Newest studies have indicated that the relationship between ethical culture and affective commitment, intention to stay, and willingness to recommend the organization to others, is partially mediated by P–O fit [20].

The extensive literatures mentioned above indicate that P–O fit is of strategic significant for both organizations and individuals in the long term. To sum up the previous researches on P–O fit and its influence on employees, it is believed that P–O fit has a significantly positive effect on employees. However, the amount of researches about its effect on organizations remains relatively small and there is a shortage of empirical evidence. Therefore, this paper, based on the domestic and foreign researches, aims to explore the effect of P–O fit on organizational effectiveness through empiric method.

42.2 Definition and Measurement of P–O Fit

The issue of P–O fit and its impact, definition and measurement indicator has been the primary problem in this field. Zheng Boxun pointed out that the implicit assumption of P–O fit was, the better the fit, the more likely positive behavior of the staff was to be produced, but how to define the degree of the fit could be the most difficult problem [28]. Scholars at home and abroad have been trying to solve the problem, but different researchers with different study purposes, selected different definitions and assumptions of P–O fit. For instance, Bem and Allen firstly developed "template comparison techniques" to compare personal properties and situational characteristics [3]. Then Chatman, through the construction of individual and organizational value profile, put forward the "profile comparison process" to compare the correlation coefficient of individuals and organizations to study matching degree [6]; Denison found that there were differences between individuals' perceived organizational values and expected organizational values, therefore, he proposed to compare this differences to measure the match degree [7]. However, Ding Hong and Zheng Boxun further used different calculation methods, such as low cut, absolute difference value, to compare this differences and measure the fit degree [9, 27]. Soumendu Biswas and Jyotsna Bhatnagar put forward from two angels to evaluate P–O fit: complementary fit occurs when the employee and the organization meet the needs of each other and the demands of organization and the abilities of the employee reach the criteria respectively, whereas supplementary fit occurs as a result of congruence of an actual (indirect) value and a perceived value between the person and the organization [4].

Although existing body of literature proposed different ways to measure P–O fit, but there are two defects in the conventional measurable indicators of P–O fit: firstly, to measure the fit degree from the difference between individuals' perceived organizational values and expected organizational values did not take the role of and mapping of employee personal values into consideration; secondly, measuring the identity, similarity of staff and organizational value does not match the actual situation, for the reason that employees may approve the organizational values due to a variety of factors though there's little similarity between them, and P–O fit may be quite good [29]. According to this, this paper puts forward a new indicator to measure P–O fit-the fulfilling degree of values, to overcome the shortcoming of existing matching measures, and to avoid the problem of how similar the values of employees and organization is, which is not easy to measure. The indicator of fulfilling degree of values views P–O fit from a dynamic perspective through comparing between the fulfilling degree of individual's values and organization's values, which has broken through the traditional boundaries.

According to the analysis above, this study chooses the indicator proposed by Zhu Qingsong and Chen Weizheng to measure P–O fit: Using the fit of fulfilling degree of employee-organization's values to measure P–O fit.

42.3 Definition of Organization Effectiveness

Up to now, there is still no agreement on the definition of organizational effectiveness. Drucker argued that effectiveness was the ability to set and achieve appropriate goals. In other words, it was the capability to do right things, which includes two aspects: first, goals must be set appropriately; second, goals must be implemented. In addition, how to set the standards of organizational effectiveness should be determined by at least eight aspects:

1. market conditions or market share,
2. creativity,
3. productivity,
4. material and financial resources,
5. profit margins,

6. managers' work and responsibility,
7. employees' work and morale,
8. public responsibility [11].

However, the recently literatures (Aakanksha Kataria) have refined organizational effectiveness from eight areas proposed above to three areas: productivity, adaptability, flexibility [14]. But, for some scholars, they defined it from the organizational performance [12]. For example, Denison regarded organizational effectiveness as a superior performance in an organization, especially in the organization's output, including both the operation performance of the organization and the standard of the individual's level, such as employees' performance or customers' satisfaction [8]. Luo Min put forward that attention should be paid to three core elements when defining organizational effectiveness: the overall performance of the organization, the goal of the organization, and the general expectation of society. Therefore, organizational effectiveness is to evaluate the fulfilling degree of organization's multiple targets [17].

In general, organizational effectiveness has a wider scope, which mainly refers to the overall organizational performance, including internal and external outputs. While organizational performance only refers to the management effects. In China, we can find this difference: the effectiveness often reflects the indirect level-the attainment of goals as well as their overall performances in organization, in other words, organizational effectiveness can be performed in multiple levels. However, the performance is usually specific and direct. For example, performance management refers to the assessment of performance. Based on the analysis of organizational effectiveness mentioned above, this study puts forward that the organizational benefit and the organizational growth can be adopted to reflect organizational effectiveness, and the organizational benefit and growth indicator should be used to measure it.

42.4 Research Model

The following Fig. 42.1 shows the proposed research model:

The model as shown in Fig. 42.1 clarifies the route of how we explore the relationship between P–O fit and organizational effectiveness. First, selecting indicators of fulfilling degree of employee-organization's values as the measurable variable to testify how the employee and organization fit degree (P–O fit); Second, P–O fit as the latent variable, is to explore the explanatory power and the influence on organization effectiveness (the dependent variable); Finally, adopting SEM method to validate the model' fit indices. If the model can be tested a well fitting model, that can support the hypothesis proposed below.

Hypothesis 1 The fit of fulfilling degree of employee-organization's values has a significant explanatory power on organizational effectiveness, that is, there exists a positive effect on the organizational benefit performance and the organizational growth performance.

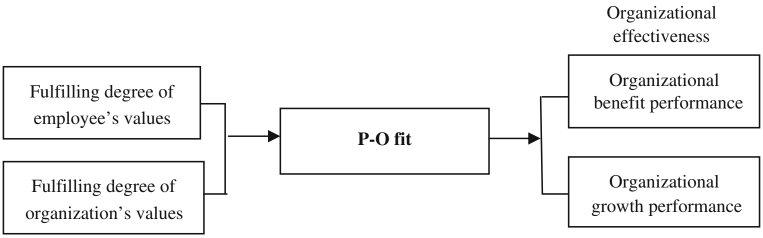

Fig. 42.1 The model of P–O fit impacting organizational effectiveness

Table 42.1 Basic characteristic of the sample ($N = 246$)

Item	N	Per.	Item	N	Per.	Item	N	Per.
Gender			Position			Age		
Female	172	69.9	General	85	34.5	> 40	61	24.8
Male	72	29.3	Middle level	118	48	30–39	123	50
Missing	2	0.8	High level	41	16.7	20–29	61	24.8
			Missing	2	0.8	Missing	1	0.4

42.5 Methodology

42.5.1 Sample

Participants in this study come from MBA classes and corporate management training classes. To ensure the quality and returned rate, questionnaires were given out and collected back on the spot. 435 copies of questionnaires have been delivered to participants and 363 have been collected back during more than six-month investigation. The returned rate was 83.3 %. There were 246 copies of valid questionnaires left after excluding 117 invalid pairs containing problems such as omissions and duplication (such as always selecting five). The demographic characteristics of the participants are showed in the Table 42.1.

42.5.2 Measuring Tools

1. Measurement of the fulfilling degree of employee's values
   In this approach two steps are needed to measure the fulfilling level of employee's values. Firstly, investigating staffs' values by the employee's value scale and calculating the fulfilling degree of each employee's value in the organization. Secondly, figuring out the mean score of the fulfilling degree of employee's values. The measurement of employee's values consists of two parts: basic values and work values.

(a) as for basic values, questionnaires designed by Rokeach with reliability of 0.93 in this study is chosen to measure them. There are two types of basic values: terminal values and instrumental values, with each type consisting of 18 items [23];

(b) as for work values, questionnaires designed by Meyer, Irving and Allen with reliability of 0.87 is chosen to measure them [18]. The scale assessed the importance of 25 kinds of job characteristics, and 21 kinds of job characteristics fell into three dimensions: comfort and security, capacity and growth, status and independence.

2. Measurement of the fulfilling degree of organization's values
   Procedures to measure the fulfilling degree of organization's values are the same as those used to measure the employee's values: First, selecting the organizational values scale to measure not only these values, but also the fulfilling level of them in the enterprise; Second, according to the score of fulfilling degree of each organizational value, the mean score of the fulfilling degree of organization's values can be figured out. In this study, the organizational values scale is mainly applied to the Chinese organization' research and designed by Taiwan scholars Ren Jinggang, Tony Huang and Zheng Boxun, with α reliability of 0.86 [22].
3. Measurement of organizational effectiveness
   The organization's comprehensive performance is assessed by a scale from the company developed by Tan and Litschert. This scale is comprised of 7 items: profits, sales, market share, sales growth, staff's morale, asset growth and competitive position [13]. Through confirmatory factor analysis, these items are divided into two dimensions: organizational benefit performance including project profit, sales revenue and market share; organizational growth performance including sales growth, staff morale, asset growth, and competitive status. The α reliability is 0.94.

42.6 Correlation Analysis Between Fulfilling Degree of Employee Organization's Values and Organizational Effectiveness

Table 42.2 presents the Pearson correlation matrix of fulfilling degree of employee-organization's values and organizational effectiveness, which shows that, the overall fulfilling degree of employee-organization's values was significantly related to organizational benefit performance dimension and organizational growth performance dimension.

Table 42.2 Correlation matrix of fulfilling degree of employee-organization's value and organizational effectiveness

Variable	Means	Standard deviations	1	2	3	4R
1 The fulfilling degree of employee's values	3.084	.900	1.000			
2 The fulfilling degree of organizational values	2.998	.801	.546**	1.000		
3 Organizational benefit performance dimension	3.100	.934	.487**	.532**	1.000	
4 Organizational growth performance dimension	2.992	.958	.617**	.593**	.783**	1.000

** $p < 0.01$, $N = 246$

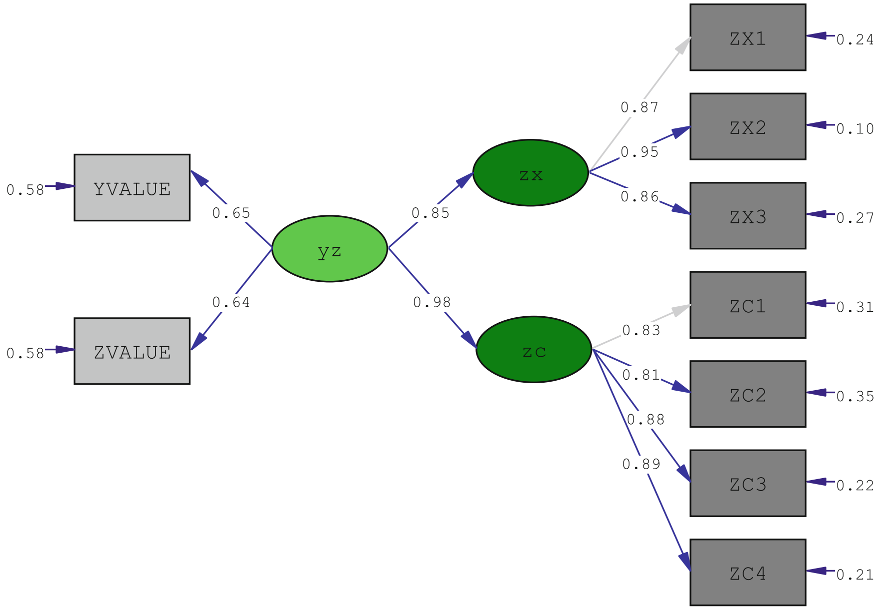

Fig. 42.2 The standard path of the model *Note YVALUE* the fulfilling degree of employee's values, *ZVALUE* the fulfilling degree of organization's values, *yz* P–O fit, *zx* organization benefit performance, *zc* organizational growth performance

42.7 Results and Analysis

The standard path of the model which displays the relationship between P–O fit and organizational effectiveness by LISREL8.54 is shown in Fig. 42.2.

As seen in the Table 42.3, we can find that the model of fit indices show that P–O fit has a significant effect on organizational effectiveness. Among these fit indices, vaule of $\chi 2/\text{df} = 2.8$ is considered to be representative of a well-fitting model; RMSEA

Table 42.3 Fit indices

	$\chi 2$/df	P	CFI	NNFI	RMSEA	SRMR
Model 1	2.84	0.00	0.99	0.98	0.087	0.036

$\chi 2/df$ Relative chi-square, *P* p-value, *CFI* Comparative fit index, *NNFI* No normed fit index, *RMSEA* Root mean square error of approximation, *SRMR* Standardized root mean square residual

is 0.087, smaller than 0.1 level put forward by Marsh and Balla, indicating that the model fit well; the CFI = 0.99, NNFI = 0.9, exceed the empirical value of 0.9 level, SRMR = 0.036, smaller than the criteria of 0.05. The overall index of the model shows that the goodness of fit is very good. Therefore, the model testifies that P–O fit could powerfully explain the organizational effectiveness. That is to say, the overall fulfilling degree of employee-organization's value has a significant effect on organizational benefit performance and organizational growth performance.

42.8 Conclusions

In this study, we examine the effects of P–O fit on organizational effectiveness. To get this goal, we select a new indictor of the fit of values' fulfilling degree to measure P–O fit, which is from a new and different perspective to define and measure P–O fit, and establish a model of P–O fit impacting organizational effectiveness. In order to test the model shown in tablea1, we adopt the SEM method to testify the fit degree. Data analyses reveal that a positive relationship between P–O fit and organizational effectiveness.

These findings provide important managerial implications. They are a practical meaningfulness for a company to how to establish and optimize environment. If one company hopes to achieve P–O fit and eventually implement organizational effectiveness, it should get the fit of fulfilling degree of employee-organization's values first, that is, should emphasize the realization of organization's values and at the same time inspires employees to fully show their individuality and realize their values. Nowadays, many companies focus more on indoctrination and shaping employee's values with organization's values, while ignoring the realization of employee's values. This paper aims to stress that companies should shift their focus from the indoctrination of values to the realization of them, to transfer from the single perspective of organization's values to the dual perspective of employee-organization's values, only by matching employee-organization's values could employees and companies reach a continuous development at the same time, finally fulfilling the bettering of the organizational benefit and growth. Therefore, our contributions are that rich the P–O fit and organizational effectiveness literature, and play a positive role in the company's management.

When discussing contributions of this research, we must take the limitations of this research into consideration. Because it is difficult for us to collect data from different resources, so we adopt self-report to assess the predictive variable and the outcome variable, which would probably lead to the problem of common method variance. Fortunately, we achieve the results by some independent measurements and the model test, so it is not particularly affected by common method variance. Moreover, Schmitt put forward that the relevant error would not lead to the false interaction, just may reduce the real interaction [24]. Nevertheless, we advise that the further research need gain the external validity by more representative random samples to further validate the model and the theoretical hypothesis of this study.

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Chapter 43
Firms' Financial Risk Forecasting Based on the Macroeconomic Fluctuations

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Abstract Firms' financial risk forecasting is generally based on firms' own financial or nonfinancial characteristics. In fact, macroeconomic fluctuation will also impact firm's financial risk. We forecast the fluctuation of financial conditions of China's manufacturing industry listed corporations based on firm's own historical financial condition and macroeconomic conditions by combining the Markov regime-switching and Z-score models. We show that our method can predict well the trends and turning-points of financial condition such as debt-asset ratio, operating activities cash flow ration and return on equity, except those which experienced sudden change in financial condition because of capital or asset restructuring.

Keywords Economic fluctuations · Financial risk · Markov regime-switching model

43.1 Introduction

Research of the World Bank shows the main reason causing bank bankruptcy is the firm's financial risk. The financial risk is usually caused by financial distress, but at last faced by the creditors and investors. Therefore, it becomes a very important way to evaluate financial risk to find indicators of financial deterioration, and then measure the financial position of borrowers or the securities issuers, and determine financial level. Based on this motivation, financial risk prediction usually converts into firm's financial difficulties prediction or financial situation measurement.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_43,

Traditionally the financial risk prediction models depend on firm's own historical data [1, 5, 8, 15]. There are some problems in those models only relying on firm's own financial data ignoring the effect of dramatic fluctuation of macro economy. Therefore, some indicators of macroeconomic fluctuations, such as stock index, begin to be introduced into financial distress prediction models. For example, Expected Default Frequency (EDF) model was established by KMV Co. Giesecke et al. [11, 12] studied corporate bond defaults to study the macroeconomic effects of major crises in the corporate bond market. also study the macroeconomic effects of bond market crises and contrast them with those resulting from banking crises using an extensive data set on corporate bond defaults in the US from 1866 to 2010.

Some Chinese scholars, such as Wu and Lu [21], Lu [20], their basic ideas about financial distress and financial bankruptcy prediction are also based on historical data of firms. In fact, macroeconomic fluctuation, such as financial crisis [20] or changes of government policies [17] may influence the macroeconomic operation in the future. As a basic element unit of economic operation, the individual firm's performance and financial situation will be impacted by the change of macroeconomic situation.

In order to study the influence of macroeconomic fluctuations to the future economy, Hamilton [16] used Markov Regime-Switching Models to study USA GNP observation data after World War II. The result showed that the periodic shift form a positive growth rate to a negative growth rate is a recurrent feature of the U.S. business cycle. Ang and Bekaert [3] used the switching models to study the configuration model of international asset. Liu et al. [19] applied Markov regime-switching to asset-pricing and established asset-pricing model on risk premium. In China, Langnan [18] used Markov mean value and variance of the transfer of two order autoregressive to study asymmetry and consistence of economic cycle fluctuation. In the study of international asset allocation, Ang and Bekaert [3] found that Markov Model was better than static analysis in forecasting the combination structure of securities investment. Guidolin et al. [13] studied the prediction effects of microeconomic factors on the return of assets. They found that Markov Model was much better than other linear asset pricing models in prediction effects.

China economy is guided and controlled mainly by government. Therefore, the fluctuation of China macro economy is a result of dual role of the government and the market, and the effects to firm may be much more obvious and direct.

Due to lack of historical database of default firm samples for China's listing corporations, the application of default prediction based on above methods is restricted in China. In this paper, we use indicators reflecting financial strength instead of default rate. Our goal is to establish a firm's financial risk prediction method based on its own historical financial data, and also considering the macroeconomic fluctuations.

43.2 Indicator Selection, Model Design and Sample Selection

1. Selection of Macroeconomic Measurement Indicator and Model Design

Currently, researches on asset return commonly believe that macroeconomics factors, i.e. inflation rate, growth rate of industrial products and variation in oil price, all are the exogenous factors that influence the future value of firm's asset. For example, Chen et al. [7] showed that growth rate of industrial products exerts great influence on the stock returns; Gersbach and Lipponer [10] examine how the correlations of bank loan defaults depend on the correlations of asset returns and how correlations and diversification are affected by macroeconomic risks. They highlight the main properties of the relationship between asset returns and default correlations, illustrating how adverse macroeconomic shocks raise not only the likelihood of defaults, but also the correlation of defaults. By separating the economy into two states or regimes, expansion and contraction, and conditioning the migration matrix on these states, Bangia [4] show that the loss distribution of credit portfolios can differ greatly, as can the concomitant level of economic capital to be assigned. Figlewski et al. [9] used firm-related factors and macroeconomic indicators i.e. unemployment rate, interest rate and inflation rate and etc. to do an empirical study Cox model, found out that firms' financial emergencies were greatly influenced by the variation of macroeconomic indicators.

We choose 7 indicators in 3 categories to reflect the status of macroeconomic operation by combining the macroeconomic factors affecting asset price and the sample characteristic of manufacturing industry. The first category includes these indicators that reflect the overall state of economy, such as Macroeconomic climate index, Consumer Price Index, RMB exchange rate, stock index and Government Bond Index. The second has those indicators that reflect the attitude of government or financial institutions to the future state of economy, such as monetary supply. And the third is reflecting the characteristics of samples of manufacturing industry, such as Producer Price Index. In the end, we select the following indicators, macroeconomic climate index, producer price index, Consumer Price Index, money supply amount, RMB exchange rate, The Shanghai Composite Index and the Government Bond Index.

Assuming at moment t, the macroeconomic condition was represented by vector Mt, and then all macroeconomic indicators can be predicted by Markov-Switching Vector Auto regression Model, which is written as:

$$M_t = \alpha_{s_t} + \beta_{s_t} M_{t-1} + \varepsilon_{s_t}. \tag{43.1}$$

In Eq. (43.1), M_{t-1} is the matrix of macroeconomic state at moment $t-1$, α_{s_t} and β_{s_t} are state-dependent coefficient matrix; ε_{s_t} is the state-dependent random items, $\varepsilon_{s_t} \sim (0, \Sigma_{s_t})$. Assuming that macroeconomics has k kinds of states, and future state of macro economy subject to the requirement of Markov chain, then the transition probability matrix of the states will be:

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1k} \\ p_{21} & p_{22} & \cdots & p_{2k} \\ \vdots & \vdots & \ddots & \vdots \\ p_{k1} & p_{k2} & \cdots & p_{kk} \end{bmatrix}.$$

In this matrix, $p_{ij} = P[S_t = j|S_{t-1} = i]$ represent the probability of macroeconomic state switch from state i at moment $t-1$ to state j at moment t, $i, j \in K$.

2. Selection of Financial Risk Measuring Indicator and Model Design

As mentioned above, researches of financial risk starts from firms' financial distress. However there are different viewpoints on how to define financial distress. Carmichael [6] regarded financial distress as being stalled when the firm was carrying on its duties, whose four forms were liquidity shortage, equity shortage, debt default and fund shortage.

Financial distress could be defined from four aspects. The first is the failure of firms, which show that the firm can still not pay for debts after liquidation. The second is statutory bankruptcy. It means the firm and debtor apply to the court for the firm bankruptcy. The third is technical bankruptcy which means the firm cannot repay debt and interest as contracted on time. The last one is accounting bankruptcy. It means the net asset in account appears to be negative; the total asset is less than the total liability. In researches of Beaver [5], there were 79 financial distress firms consisting of 59 bankruptcy firms, 16 preference-dividend-owing firms and 3 debt-owing firms. Thus Beaver defined bankruptcy, owing preference dividends and owing debts as financial distress. Altman [1] defined the financial distress as firm is in the statement of statutory bankruptcy.

Since China listing firms were almost not delisted before 2011, this article chooses accounting bankruptcy firms and technical bankruptcy firms as study objects, which book value of net assets is negative and net operating cash flow is less than current liabilities. Meanwhile, strength of solvency depends on the profitability ultimately. So we choose Debt-Asset ratio (DAR), Operating Cash Flow Ratio (OCF) and Return on Equity (ROE) as measuring indicators.

Although financial indicators are broadly effectively used in financial distress prediction models, there is disagreement on how to choose the indictors and whether the best indicators exist. However, there is no better financial indicator prediction model after the establishment of Altman's Z score model [1] and ZETA model [2].

Therefore, this article chooses 5 indicators of the Z score model as the independent variables for financial risk measurement. These indicators are $X1$ (WC/TA), $X2$ (RE/TA), $X3$ (EBIT/TA), $X4$ (MVE/TL) and $X5$ (S/TA). Choose 3 indicators, DAR, OCF and ROE as dependent variables.

Model as follows,

$$CR_{i,k} = a_{i,s_t} + b_{i,s_t} X_{i,t} + \xi_{i,s_t}. \tag{43.2}$$

In this model, $CR_{i,t}$ refers to the financial risk measure matrix which is made up of DAR, OCF and ROE of firm i in term t; a_{i,s_t} and b_{i,s_t} refer to State-dependent coefficients matrix; $X_{i,t}$ refers to firm i's financial risk measure independent variable matrix at time t, i.e. $X_{i,t} = [x1_{i,t}, x2_{i,t}, x3_{i,t}, x4_{i,t}, x5_{i,t}]$.

The estimate of state dependent coefficient of the firm in model (43.2) is based on the posterior probability of each state of the self-regression model (model (43.1)) in macro-economic status. To be specific, the posteriori probabilities of each state in model (43.1) serve as the corresponding weight coefficient of multiple linear regression of firm i in the model (43.2). Compared with Altman Z score calculation methods, the linear regression coefficient in the firm's financial indicators in model (43.2) present different value under various macroeconomic conditions. We argue that our dynamic coefficient model is better than Altman' Z score model used fixed coefficient.

3. Sample Selection

Macroeconomic fluctuations have different influences on the financial risk of firms in different industries. In order to decrease the effect of industries' difference, we choose sample firms in the same industry. In China's listing firms, the manufacturing industry has the largest sample firms, so we choose them as research samples. The samples' data period is from Jan. 1st, 2003 to Sep. 30th, 2011. After eliminate those firms with incomplete data, we have 488 sample firms with 35 quarterly financial data. All the data of listing firms come from CSMAR database, and macroeconomic data mainly come from macro database of caixin.com.

43.3 Firms' Financial Risk Prediction Results and Analysis

1. Comparison and Analysis of the Prediction and the Actual Value

After calculating the transition probability matrix, posterior probability and the relationship model of all macroeconomic factors in different macroeconomic conditions, according to the model (43.2), DAR, OCF and ROE of each sample in different periods can be predicted. The comparisons between predicted value and actual value of DAR, ROE and OCF in the 1st listed manufacturing firm (listing code 000012) are presented in Figs. 43.1, 43.2, 43.3 respectively.

From Figs. 43.1 to 43.3, we can see that although at certain times predicted value and actual value are opposite or different significantly, the overall fitting effect is very satisfactory. The 3 indicators of predicted value and actual value are very close. Furthermore, the major turning points of 3 indicators can be predicted effectively.

2. Overall Analysis of Predicted Results

In order to evaluate the whole forecasting effect, we choose 488 samples to compute root mean square error (RMSE) of predicted value and actual value in the

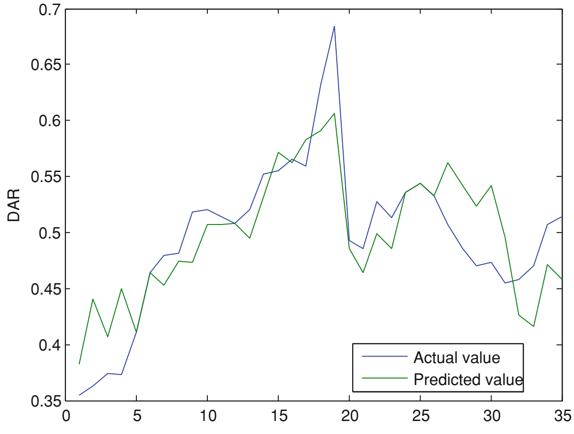


Fig. 43.1 Predicted value and actual value of DAR

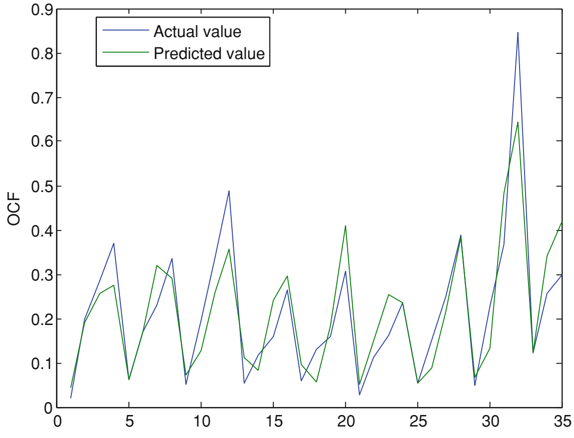


Fig. 43.2 Predicted value and actual value of OCF

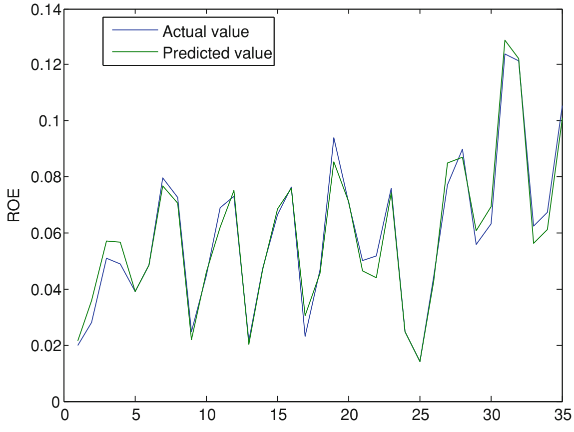


Fig. 43.3 Predicted value and actual value of ROE

observation period in terms of the DAR, OCF and ROE, calculation formula as Eq. (43.3), calculation results as Figs. 43.4, 43.5, 43.6, 43.7, 43.8, 43.9,

$$\mathrm{RMSE}(\hat{\theta}) = \sqrt{\frac{\sum(\hat{\theta} - \theta)^2}{N - 1}}. \tag{43.3}$$

In the Eq. (43.3), $\hat{\theta}$ is predict value, θ is the actual value, N is the number of the observation period.

(1) The analysis of the prediction value of DAR

Figures 43.4 and 43.5 show that in 488 firms (except for several individuals), most samples DAR of RMSE of prediction values and deviate from the actual value is small. Among them, the number of firms whose RMSE is less than 0.04 is 393, occupying 80.53 %, and which RMSE is greater than 0.06 is only 26 firms, occupying 5.33 %. The overall prediction is very good.

(2) Analysis of the prediction value of OCF

From Figs. 43.6 and 43.7, we can see that in 488 firms except some individual firms, the deviation of expected value and actual value of OCF is small. In Fig. 43.7, the number of firms whose RMSE is lower than 0.10 is 362, occupying 74.18 %; the number of firms whose RMSE is between 0.10 and 0.20 is 103, occupying 21.11 %. The percentage of these two parts is 95.18 %, and it shows the overall prediction is good.

(3) The analysis of the prediction value of ROE

From Figs. 43.8 and 43.9, we can see that in all 488 firm samples, except for individual firms, the number of these firms whose deviations of predicted value and actual value of ROE are small. In Fig. 43.9, the number of firms whose RMSE is less than 0.02 is 416, 85.25 % of total firms; the number of firms whose RMSE is between 0.02 and 0.04 is 15, 3.07 % of total firms. The above RMSE is less than 0.04, 88.32 % of total firms. The whole prediction is very good.

3. Analysis of Prediction Abnormal

Based on Figs. 43.4, 43.6, 43.8, we choose these firms to analyze further, whose RMSE of DAR of the predicted value and the actual value is higher than 0.06, and RMSE of OCF of the predicted value and the actual value higher than 0.20, and RMSE of ROE of the predicted value and the actual value higher than 0.10. We filter about 85 firm samples. Among them, there are 14 firms to exist prediction and actual abnormal in two indicators. The main reason of prediction abnormal is the unexpected change of financial situation caused by capital and asset restructuring.

There are 26 firms whose RMSE of DAR of the predicted value and the actual value higher than 0.06, of which 8 firms are renamed after the reorganization of assets, and 7 firms once experienced ST or * ST.

23 firms' RMSE of OCF is higher than 0.20, of which there are 4 firms renamed after the reorganization of assets, 1 has history of ST, and 1 firm has large asset restructuring.

Fig. 43.4 The RMSE between the predicted value and the actual value of DRA

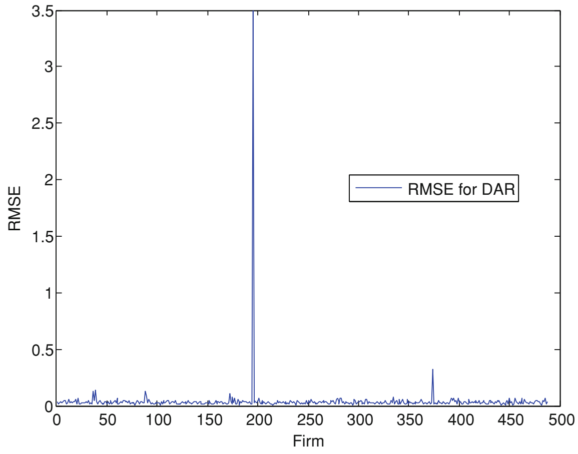


Fig. 43.5 The quantity distribution of RMSE between the predicted value and the actual value of DAR

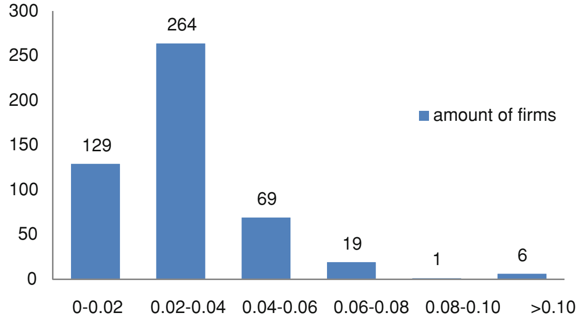
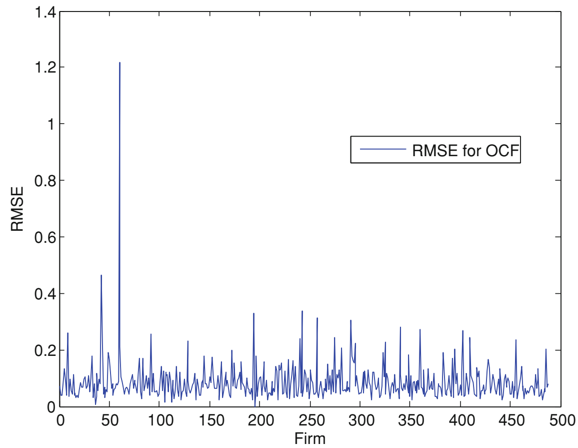


Fig. 43.6 RMSE of the predicted value and actual value on OCF



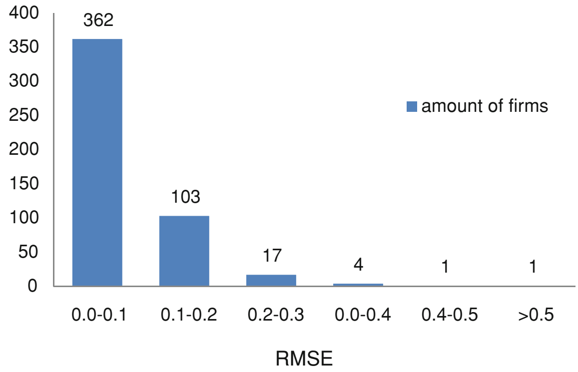


Fig. 43.7 The number distribution of firms of RMSE of the predicted value and actual value on OCF

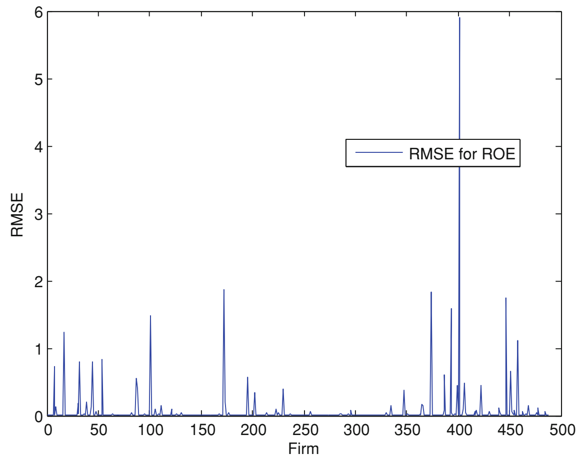


Fig. 43.8 RMSE of the predicted value and actual value on ROE

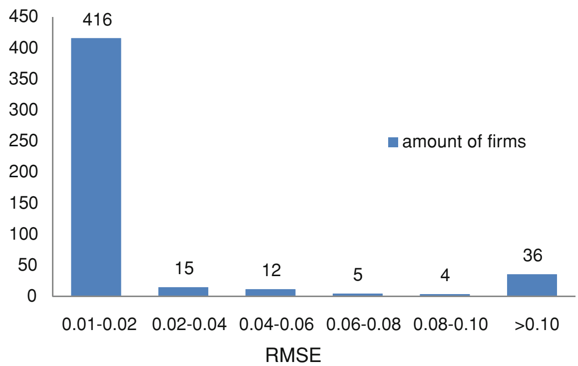


Fig. 43.9 The number distribution of RMSE of the predicted value and actual value on ROE

There are 36 firms whose RMSE of ROE of predicted value and actual value higher than 0.1, of which 15 are renamed after the reorganization of assets, and 21 firms experienced ST or * ST.

43.4 Research Conclusion and Application Prospect

1. Research Conclusion

This article combines Markov Regime-switching model and Z Score method to predict future finance trend and turning point by referring firm's historical financial positions based on the fluctuation of macro-economy. In the process of analysis, we predict the future by choosing some indicators which can reflect financial risk of listing firms, such as DAR, OCF and ROE. Our research shows that the prediction method of this article can accurately predict the future financial risk of the sample firms and work effectively in forecasting listed firms' financial positions and in anticipating turning points, except ST firms with extremely worsening financial situation and those firms whose financial situations totally changed through asset restructuring.

2. Application Prospect

This article applies the Markov Regime Switching Model to predict firm financial risk. It achieves the goal of micro-prediction by combining the firms' historical financial situation and the future macro-economic operation situation. If financial risk analysis and prediction framework is successfully used, the financial institutions can evaluate firms' financial situation based on prediction of macro-economic operation situation so as to avoid financial loss due to macro-economic fluctuations. Therefore, this shall have broad prospects and further developments facing the undulating macro-economic circumstances.

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Chapter 44
Relationship Between Social Responsibility and Economic Benefits of Liquor Industry

Yixin Zhang, Shuhua Yang and Liming Yao

Abstract From an aspect of the present state of the liquor industry, we firstly determined the research questions of social responsibility and economic benefits of liquor industry. Secondly we designed the research train, further clarified which on the basis of the theoretical review and literature. We developed the multi-angle, multi-level study through theoretical research and selection of economic benefits indicator. Establishment of social responsibility evaluation index system, multiple linear regression analysis based on principal components regression, and case studies proposed also. Then finally, we made conclusions and proposed suggestions on the basis of the study.

Keywords Liquor industry · Social responsibility · Economic benefit · Principal components regression

44.1 Introduction

With the high developing speed of Chinese economy, Chinese enterprises have got great achievements on business. However, the unilateral pursuit of economic interests has resulted in a great deal of social problems. Such as some companies damaged the legal rights of the employees, violated the consumer's rights and many entities are lack of good faith. Be defaulted maliciously, be bankrupt in order to avoid liabilities and disclose fake information etc. is the examples in such context.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_44,

China's liquor industry is definitely the best in the world in terms of scale, the product output and the number of enterprises. Liquor industry, with independent intellectual property rights, is characterized as unique and competitive industry. As China's unique traditional kinds of wine with a long history, liquor formed its own wine culture and occupied an irreplaceable position in the minds of consumers. The economic benefits it creates, second only to the tobacco industry in the food industry, take part a significant financial contribution for national financial resources. As an industry with profound culture, an urgent problem currently is that how to deal with the relationship between social responsibility and economic benefits.

The research conclusion towards relationship of corporate social responsibility and economic benefits (mainly for corporate performance) are different. There are three main types of views: positive correlation, negative correlation and uncorrelated theory. Representative scholars on the positive correlation are Bragdon and Marlin [4], Bowman and Haire [3], Parket and EilBert [10], Heinze [8] and Sturdivant and Ginter [11] and so on. These scholars used accounting indicators to measure corporate performance and noted that corporate social responsibility can improve the performance of enterprises. A representative on the negative correlation is Vance [12]. He believes that fulfilling corporate social responsibility will reduce corporate performance. Because fulfilling social responsibility leads to a corresponding cost. Relatively to other enterprises which do not fulfill social responsibility. It makes a company at a competitive disadvantage and leads to decline in corporate performance. The main representatives on uncorrelated theory are Alexander and Buchholz [2], and Abbott and Monsen [1], they do not think there is a correlation between fulfilling corporate social responsibility and its performance.

44.2 Problem Description

Correlation means batch correlation between things. In the nature as well as the economic sphere, there are a large number of relevant phenomena, such as water ice and temperature, inflation and money supply related, etc. So, is there a correlation between social responsibility and economic benefits of liquor industry?

As for an industry, its social responsibility depends on social responsibility of all enterprises in the industry. In this study we regard corporate economic benefits and social responsibility in liquor industry as variables. Assume that corporate economic benefits is a function of corporate social responsibility, expressed as $Y = f(X)$. Build evaluation index system. And analyze the correlation between economic benefits and social responsibility. As shown in Fig. 44.1.

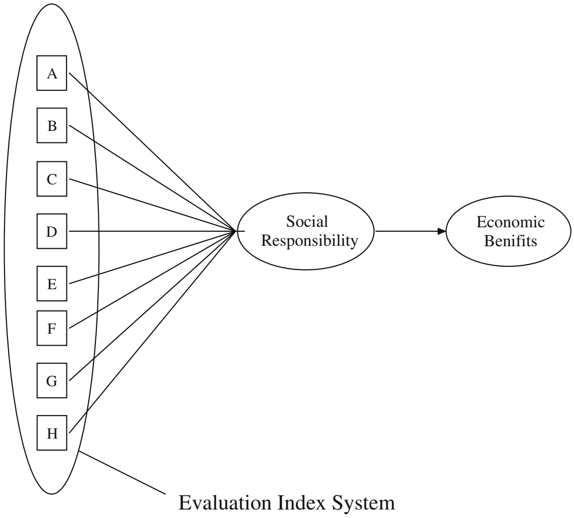


Fig. 44.1 Theoretical model

44.3 Methods

44.3.1 Establishment of Index System

1. Economic Measure

Economic benefits mean social labor savings by foreign exchange of goods and labor. From the definition of economic benefits, we know that it is a comparison of the operating results with the labor cost, or simply the relationship between income and expenses. That is, any expression of the relationship between the income and the expenses belongs to the category of economic benefits.

On one hand, it is an important problem that how to assess economic benefits of production units accurately. Currently, there are different understandings of economic benefits. Mostly we use profits or profit indicators to measure economic benefits of enterprises.

On the other hand, there are two kinds of economic benefits evaluation indicators, i.e. accounting indicators and market indicators. The values of accounting indicators are mainly from the financial statements audited by certified public accountants. Market indicators are displayed based on the capital market trading. In Chinese capital market, both regulatory mechanism and the degree of rational investors are imperfect, to some extent. Using market indicators is not comprehensive. So this paper adopts an accounting indicator: operating profit.

2. Measure of Social Responsibility

Corporate Social Responsibility originates in the late 19th century, and corporate social responsibility theory and stakeholder theory gradually converge in the

Table 44.1 Social responsibility evaluation index system

Social responsibility index	Bonus share allocation ratio of profits
	Asset-liability ratio
	Taxes paid
	R&D spending
	Credit scores
	Wages and benefits expenses
	Donations
	Brand value

1990s. The earliest scholars of stakeholder theory is Carroll [6] and Clarkson [7]. According to Clarkson's definition of stakeholder and Carol's classification of corporate four social responsibility [5], this paper defines Corporate Social Responsibility as: Enterprises for the purpose of sustainable development, in the pursuit of profit maximization, at the same time, also undertake economic, legal, ethics and voluntary responsibility of shareholders including shareholders, creditors, employees, customers, business partners, governments, communities, and environment and so on.

In the actual management practices, corporate social responsibility is immeasurable potential variables. We need to use observable subdivision indicators to describe these potential variables, thereby gaining available statistical data. Based on the concept of CSR, this paper designs the indicator system, in combination with the actual situation of Chinese liquor enterprises. Following a quantitative and comprehensive, available, and meaningful principle, the indicator system is shown in Table 44.1.

44.3.2 Multiple Linear Regression Analysis

Regard economic benefits indicator as dependent variable and social responsibility indicators as independent variables. And establish a multiple linear regression model to calculate the parameter estimates of the regression equation, i.e. an estimate of Y. Then obtain the effects of the regression equation, i.e. the effect of correlation between Y and X. General model is:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 x_5 + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8,$$

Y represents operating profit, X_i represents social responsibility indicator.

44.3.3 Principal Component Regression

Principal component regression, put forward by Massy [9], is a kind of biased estimation method of dealing with the multicollinearity. It originated in the principal component analysis. And its core idea is to make multiple indicators into a few comprehensive indexes without changing the index system. These comprehensive indicators are main components. Treat them as new independent variables, and then use the OLS method to estimate parameters in the model. Finally, transform the principal components into original independent variables.

Identify eight main components of the independent variable group, and select the previous k principal components that contains the most information of original variable group. Establish a regression equation between Y and the previous k principal components. And then transform the k principal components into the original independent variables to obtain the expression on Y and X.

44.4 Case Study

44.4.1 Data Collection

Select 13 listed companies in liquor industry as research samples. To ensure the objectivity and impartiality of the data, we need to base on annual reports of listed companies. Annual reports of enterprises are results of CPA's audit, so they have some validity and authority. Take the effects of extreme values on the statistical results into account. We eliminate ST and PT companies with poor business performance. Based on corporate annual reports and social responsibility reports, we collected data about listed companies in liquor industry. As shown in Table 44.2.

44.4.2 Multiple Linear Regression Analysis

44.4.2.1 Correlation Analysis

Use Eviews to get the correlation coefficient matrix, as shown in Table 44.3. There exists correlation between economic benefits indicator and social responsibility indicators. Except with a weak correlation with asset-liability ratio, correlation with other independent variables is strong. So it is reasonable to establish a linear regression model between dependent variable and independent variables.

44.4.2.2 The Diagnosis of Multicollinearity

There are many ways on reconnaissance of multicollinearity. We use pair wise correlation coefficients between dependent variables and independent variables to investigate. As shown in tab3, some correlation coefficients between Y and X are high. So there exists Multicollinearity. To avoid the regression parameter estimation problem and other problems, do principal component regression of independent variables.

Table 44.2 Original data table

	Operating profit (yuan)	Bonus share allocation ratio of profits (%)	Asset-liability ratio (%)	Taxes paid (yuan)	R&D spending (yuan)	Credit scores	Wages and benefits expenses (yuan)	Donations (yuan)	Brand value (billion yuan)
Kweichow Moutai	18,830,739,817.65	26.89	21.21	10,170,840,319.22	632307654.00	87.4	2,953,919,072.54	139750000	748.05
Wuliangye	13,702,135,270.70	18.77	30.34	9,072,901,623.78	568,952,900	72.6	2,539,978,448.13	19420000	712.78
LuzhouLaoJiao	6,089,363,956.27	16.14	37.26	3,582,818,501.59	70,203,055.80	68.2	237,184,243.57	11680604	281.46
Swellfun	509,985,959.13	5.52	28.50	627,310,939.59	3,741,638.51	63.2	192,676,231.74	344,200.00	76.68
Gujinggong	953,901,678.97	7.74	36.41	1,556,750,391.03	174,362,000	80	722,698,221.19	100,000.00	208.99
YangheBrewery	8,188,760,899.97	24.65	37.82	5,517,291,895.28	45090700	79	701,417,518.30	25604600	321.72
Jiuguijiu	642,845,713.46	3.94	25.64	690,376,783.67	27,094,948.07	72	131,024,061.70	1,631,000.00	66.76
Tuopai hede	496,036,515.39	7.31	32.48	388,795,399.78	8,086,637.67	34	211,381,740.45	1,500,000.00	44.75
Shanxi Fenjiu	2,015,144,420.82	16.86	40.70	2,726,612,089.38	10,755,089.58	75	632,552,808.12	0.00	166.15
Golden Seed Winery	749,824,573.97	10.91	25.74	695,113,004.69	3,161,010.05	78.6	190,066,095.46	603,000.00	89.06
Laobaigan Liqour	147,766,482.43	20.40	63.12	329,764,711.71	2,521,638.26	36.80	141,424,988.92	0.00	48.32
Green barley wine	380,074,045.51	9.66	7.25	489,876,076.02	8,380,025.03	50	100,378,309.92	3,000,000.00	55.21

Table 44.3 The correlation coefficient matrix (keep three decimal places)

	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
Y	1.000								
X_1	0.754	1.000							
X_2	−0.224	0.146	1.000						
X_3	0.987	0.760	−0.189	1.000					
X_4	0.905	0.537	−0.245	0.900	1.000				
X_5	0.542	0.356	−0.354	0.582	0.474	1.000			
X_6	0.931	0.627	−0.218	0.939	0.980	0.516	1.000		
X_7	0.850	0.643	−0.278	0.778	0.768	0.453	0.794	1.000	
X_8	0.975	0.694	−0.205	0.986	0.951	0.580	0.964	0.763	1.000

Table 44.4 Principal component analysis for independent variables

Number	Value	Difference	Proportion	Cumulative value	Cumulative proportion
1	5.458966	4.260813	0.6824	5.458966	0.6824
2	1.198153	0.589923	0.1498	6.657119	0.8321
3	0.608230	0.178879	0.0760	7.265349	0.9082
4	0.429350	0.186690	0.0537	7.694699	0.9618
5	0.242660	0.197533	0.0303	7.937360	0.9922
6	0.045127	0.028409	0.0056	7.982487	0.9978
7	0.016718	0.015924	0.0021	7.999205	0.9999
8	0.000795	–	0.0001	8.000000	1.0000

44.4.3 Principal Component Regression

Do principal component analysis of eight independent variables. Obtain eigenvalues, contribution rates and the cumulative contribution rates. As shown in Table 44.4.

In the scree plot, as shown in Fig. 44.2, there is an obvious inflection point. The scree plot shows the proportion of eigenvalues of extracted principal components accounting for. Principal components before the inflection point reflect most of information. The curve after the inflection point is relatively smooth, and it means that it reflects relatively small proportion of information. The inflection point is between the second and third principal component, so just extract the first two main components.

Variable loading plot (Fig. 44.3) shows variable loading factor of corresponding principal components and how to synthesize principal components in accordance with original independent variables. The Table 44.4 and Fig. 44.3 show that contribution of the first principal component was 68.2 %, which loads mainly on X_1 and X_3. So the first principal components mainly reflect the share out bonus of distributable profit ratio and asset-liability ratio influence on economic benefits. Thus, name it as the return to shareholders factor. The second principal component contribution rate is 15.0 %. It loads higher on indicators such as X_8. So it mainly reflects the enterprise credit score, donating the impact on the economic benefits, and so on. Thus name it as macro factor contribution to society.

Fig. 44.2 Scree plot

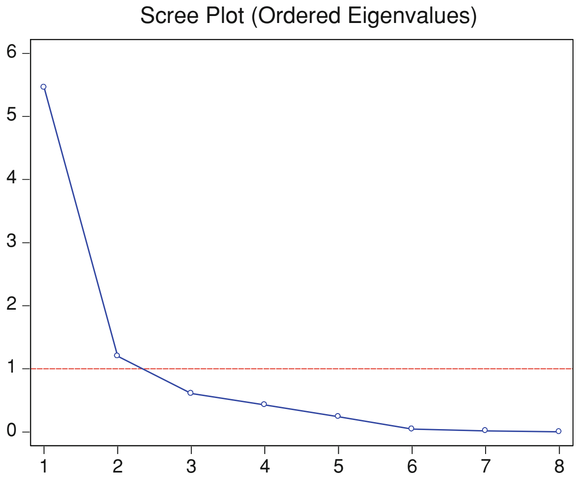
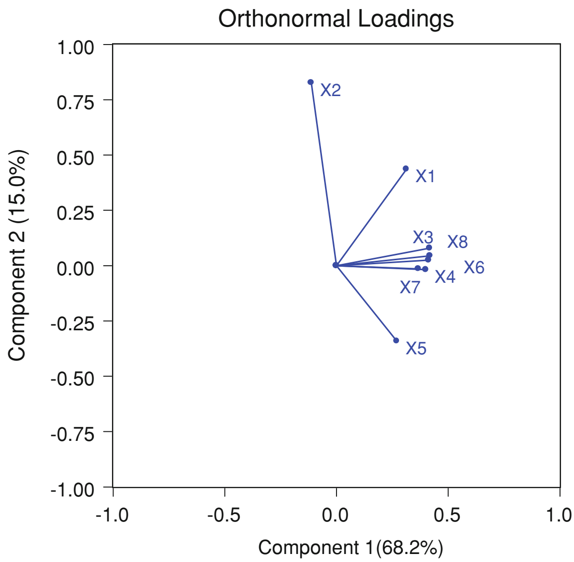


Fig. 44.3 Variable loading plot



As Table 44.4 shows, the first two principal components cumulative contribution rate is 83.21 %. The eigenvectors corresponding to the first two eigenvalues are shown in Table 44.5.

We can get the expression of the principal component:

$$\begin{cases} F_1 = 0.313524X_1 - 0.1133X_2 + 0.418057X_3 + 0.400339X_4 \\ \qquad +0.270663X_5 + 0.412882X_6 + 0.366831X_7 + 0.41896X_8 \\ F_2 = 0.43645X_1 + 0.826487X_2 + 0.079136X_3 - 0.01835X_4 \\ \qquad -0.34211X_5 + 0.025024X_6 - 0.01427X_{10} + 0.04431X_8. \end{cases} \quad (44.1)$$

Table 44.5 Coefficient matrix expression of principal components

Variable	PC 1	PC 2
X_1	0.313524	0.436450
X_2	−0.113299	0.826487
X_3	0.418057	0.079136
X_4	0.400339	−0.018351
X_5	0.270663	−0.342109
X_6	0.412882	0.025024
X_7	0.366831	−0.014269
X_8	0.418960	0.044310

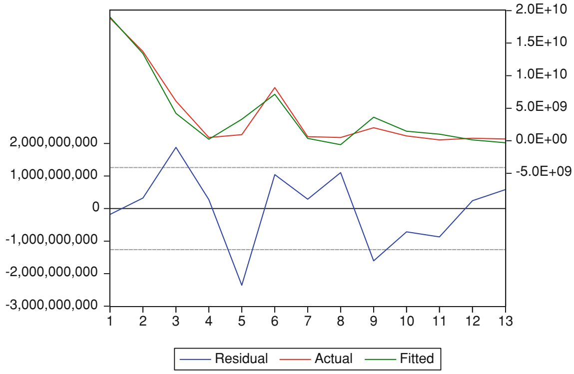


Fig. 44.4 Make a comparison chart of the actual value and the fitted values

44.4.3.1 Multiple Linear Regression Model Based on Principal Components Estimate

According to the results of regression analysis, do regression analysis for y with the two principal components. It follows from Table 44.5 that

1. The regression equation is: $Y = 4.08 \times 10^9 + 5.68 \times 10^9 F_1 + 3.95 \times 10^8 F_2$.
2. It can be seen that the equation was good. The adjusted coefficient of determination is 0.956233 and instructions liquor business operating profit appears from these changes can have a 86.2916 % of the two principal components explained.

Replace F_1 and F_2 with the linear combination of X_i, and we can get the regression equation of Y and X:

$$\begin{aligned} Y = {} & 4.08 \times 10^9 + 1.95 \times 10^9 X_1 - 3.17 \times 10^8 X_2 + 2.41 \times 10^9 X_3 \\ & + 2.27 \times 10^9 X_4 + 1.40 \times 10^8 X_5 + 2.36 \times 10^9 X_6 + 2.08 \times 10^9 X_7 \\ & + 2.40 \times 10^9 X_8 + \beta_6 x_6 + \beta_7 x_7 + \beta_8 x_8. \end{aligned}$$

Make a comparison chart of the actual value and the fitted values. The Fig. 44.4 shows that the model fits in well.

44.5 Policies and Proposals

Based on the above analysis of the relationship between economic benefits and social responsibility, policy recommendations are as follows:

1. Improve the basic framework associated with liquor industry social responsibility. We suggest that the market parties jointly improve the basic framework related to social responsibility, including further regulating social responsibility reports, preparing social responsibility indicators and so on. Standardized evaluation system helps to evaluate the performance of liquor industry social responsibility. And promote the sustainable development of society.
2. Establish incentive mechanisms corresponding to social responsibility evaluation system. The goal of any evaluation system is to encourage companies to perform related duties, and corporate social responsibility evaluation system is no exception. We can evaluate the fulfillment of corporate social responsibility in liquor industry. So as to evaluate the liquor industry's social responsibility.
3. Change liquor enterprises' understanding of social responsibility, and promote the fulfillment of social responsibility effectively. Corporate social responsibility should be integrated into development strategies. Fulfill the responsibilities to individual shareholders, creditors, suppliers, employees, consumers, the environment, government, and others from the strategic point of view. For example, liquor enterprises should create a good working environment for employees. Improve employee benefits so as to improve the enthusiasm and creativity of employees and create more value for their businesses.
4. Strengthen policy's formulation and guide enterprises to fulfill their social responsibilities effectively. Government should develop appropriate policies to guide liquor enterprises to pay more attention to the interests of employees, suppliers, customers and other stakeholders. Encourage enterprises to focus on environmental protection and energy saving in the production process. Only by developing policies and regulations, can we fulfill the liquor industry's social responsibility effectively.

44.6 Conclusions

The main purpose of this paper is to study the relationship between economic benefit and social responsibility in liquor industry. This plays a positive role in Chinese liquor corporate promoting social responsibility. Conclusions of this paper are as follows:

As for the concept of social responsibility, scholars have not reached a consensus. This paper defines social responsibility from the perspective of stakeholders theory. As for liquor industry, corporate social responsibility has a positive impact on economic benefits. Similarly, the economic benefits have a good role in fulfilling social responsibility. There is a positive correlation between the two. And they promote each other.

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).

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Chapter 45
Dissimilar Welding Using Spot Magnetic Pulse Welding

Guillaume Racineux, Arun Prasath Manogaran, Diogo Pereira and Rosa M. Miranda

Abstract Magnetic Pulse Welding (MPW) is a solid state joining technique which have increased development in the past few years due to the industrial need in joining dissimilar materials and difficult-to-weld ones. It is an impact welding technique, such as explosive welding (EXW) and laser impact welding (LIW), which share the same basic joining principle, impact-driven solid state welding, but applied to different scales: EXW for larger parts and LIW for smaller. Defined as a fast, reliable and cost-effective technique, MPW struggles with the lack of knowledge about the welding process despite of the extensive existing literature. The work conducted aimed at joining Al to steel in spot welding configuration widely used in automotive industry. Welds were characterized in order to understand and improve the process.

Keywords Magnetic pulse welding · Spot welding · Solid state joining · Aluminum alloys · Steel

45.1 Introduction

MPW uses the concepts of electromagnetism in its fundamentals [4, 5]. When a very high AC current in the order of 1 million ampere is forced to passed through a conductive coil, or inductor near an electrically conductive material, an intense magnetic field is locally produced that generates a secondary current in the flyer according to the Lorenz law. The effect of this current moving in the magnetic field

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_45,

of the primary current generates a Lorenz force which accelerates the flyer at a very high velocity of about 800 m/s. When the flyer targets a base material a very strong collision occurs creating a jet consisting of both metals, air and surface oxides removed from materials surfaces. The parts are forced to bond together in a solid state weld. The kinetic energy of the flyer is transformed into heat by the intense plastic deformation of the material surfaces [3]. The generated heat locally increases the temperature softening the material or producing strain hardening depending on the materials characteristics. Eventually, highly localized fusion may occur. The time interval for heating and cooling is very rapid, in the order of milliseconds, so heat is rapidly dissipated into the bulk material and no heat affected zone is observed. The process is considered in solid state since no fusion of bulk material occurs and the joint is produced by severe plastic deformation of the interfaces contacting at high speed. So, it is particularly adequate to join dissimilar materials with very distinct thermophysical properties and melting points as Al allows and steels used in automotive industry [1].

Recently, advances have been made to adapt the process to spot welding configurations replacing resistance spot welding. Air gap is an important requirement to accelerate one of the parts at a high velocity to impact on to the other to form a joint. The specificity of magnetic pulse spot welding (MPSW) is that both the sheets are in contact with each other without any gap before and after welding. So, in order to achieve spot welding using magnetic pulse, a previous local stamping is performed on the spot welding location, to form a “hump” on the flyer part. When the two sheets are placed together to perform spot welding, this hump made on the flyer part forms an air gap with the other fixed part. The inductor is designed in such a way that it is placed just above the hump. When the current is discharged, the hump deforms and impacts onto the fixed material at a very high velocity, resulting in a spot welding. Generally, the sheet with good electrical conductor is chosen as the flyer part [2] and the hump geometry determines the size of the spot weld.

45.2 Experimental Procedure

In this study Magnetic Pulse Welding spots of AA1199 with 0.5 mm thick to mild steel EN355 with a thickness of 1.5 mm was performed. The process uses a monolayer I shaped flat inductor that concentrates the magnetic flux on the surface of the flyer hump as schematically depicted in Fig. 45.1.

The generator used for carrying out welding is developed at Ecole Centrale de Nantes which has a capacitance of 272 μF, an inductance of 0.5 μF and maximum energy of 30 kJ. Trials were performed with energy varying between 2.8 and 4.1 kJ.

Figure 45.2 shows the inductor and the connector before welding and the hump in Al sheet is shown in Fig. 45.3. The standoff distance between the coil and the flyer material was of 0.2 mm.

Samples were welded and cut for microstructural analysis under optical and scanning electron microscopies.

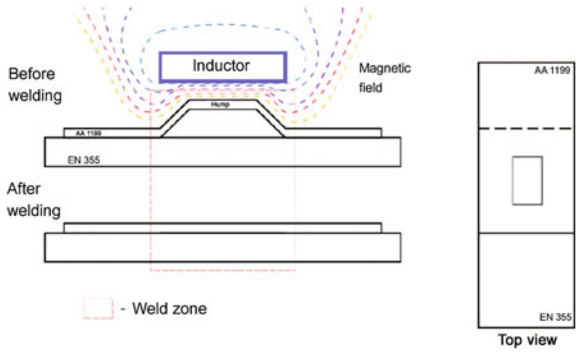


Fig. 45.1 Schematics of MPW for spot welding

Fig. 45.2 Inductor and connector clamped before welding

Fig. 45.3 Humps in the Al plate

45.3 Results and Discussion

The optical analysis revealed a welding characterized by an unbound region at the centre with two welded zones on each side as shown in Fig. 45.4.

Marya et al. [4] reported that the high collision velocity is sufficient to peel off the oxide layer on the surface of the colliding contact area. The center part of the hump metal is sprayed at the collision apex and forced outward with high velocity in two directions opposite from the center. The mixture of the peeled surface oxide and the surrounding gas forms the jet that propagates along the two colliding surfaces in a swirl motion in both the directions opposite from the center and cleans the metal surface layer.

The two clean metal surfaces are thus pushed into intimate contact by the short time duration high pressure, which leads to the metallurgical bonding across the interface. As long as the jetting is sufficient, the continuous wave interface can be

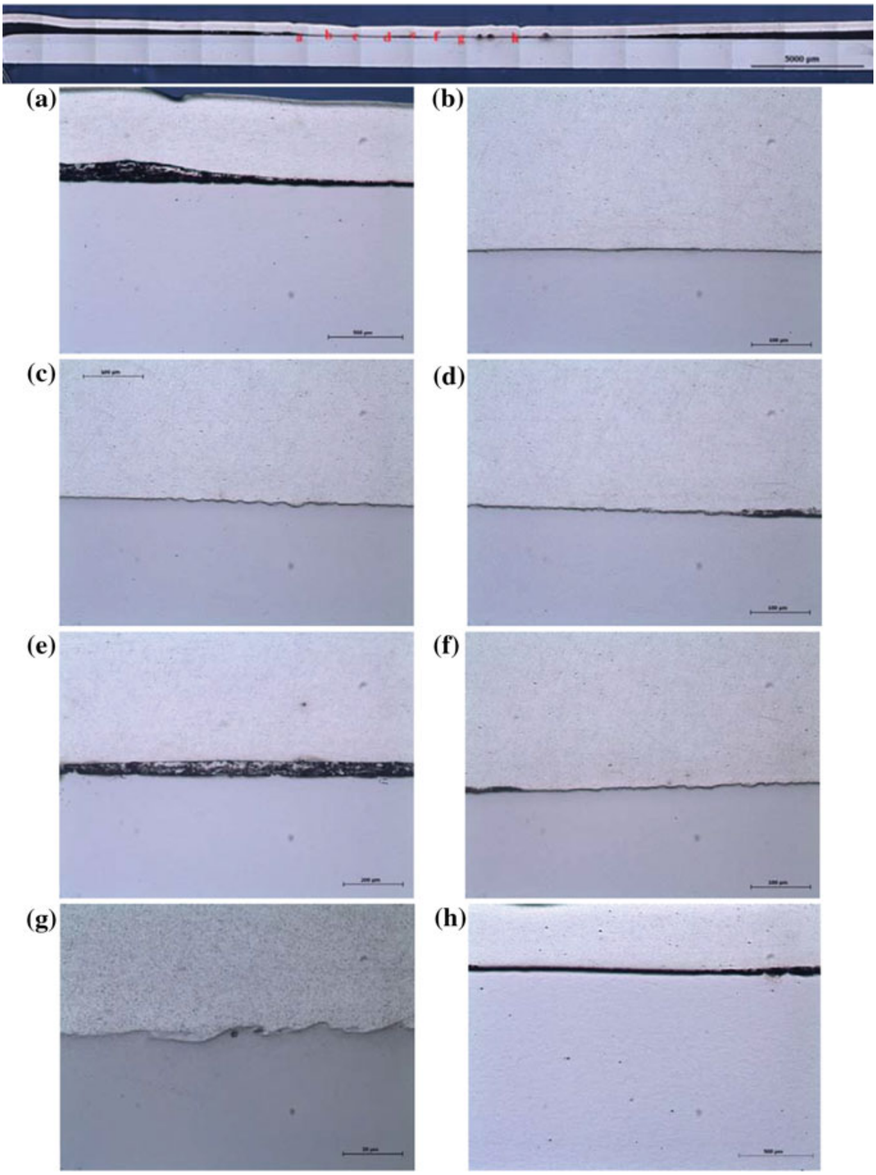


Fig. 45.4 Macrograph of the weld cross section and details

formed. If there is insufficient jetting, the metal surfaces will result in little or no bonding.

The important conditions for jetting to form depend on the collision point velocity and the collision angle. At the critical collision angle, if the jetting exceeds the

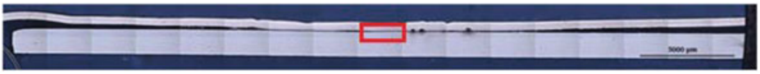


Fig. 45.5 SEM analysis zone

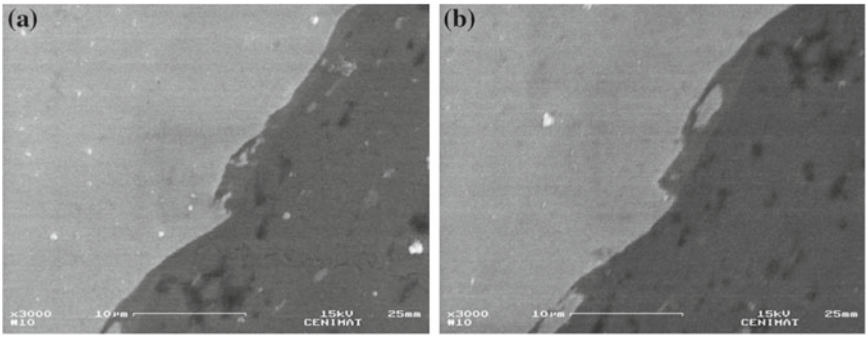


Fig. 45.6 SEM detail of the bonded zone (secondary electron analysis mode)

dynamic elastic limit of the materials, the plastic deformation occurs on the metal surface and bonding can be formed. However, unlike the explosive welding process, the wavy surfaces in the MPSW are in two opposite directions from the center of the hump. The high velocity impact welded interface morphology resulted from jet effect can be classified into two types: (1) flat interface at the center of the weld, (2) wave interface with pocket type and continuous transition layer along the interface in the bond zone in two different directions from the center.

As it can be seen in the details presented below, a bonding wavy interface is visible on both sides (detail c and f) of the unbound central region (detail e) presenting similar welding lengths. Furthermore, the welding zone is centred with the deformed zone. The centre unbounded zone presented trapped debris (detail e).

SEM analysis was carried out in the zone marked in Fig. 45.5 which represents one of the bonded zones. In the details presented below the darker region represents the aluminium. Figure 45.6 detail (a) shows that bonding was achieved while in detail (b) embedded steel particles can be seen in the aluminium. Figure 45.7 shows the wavy interface, typical feature of impact welding and in (b) a wave detail with a steel particle embedded in aluminium.

The wave amplitude is found to be around 2–5 μm from the center of the interface and the wave length is around 2×10 mm^2 across the weld interface. Beyond that, there is no waves because, the critical collision angle and velocity is not sufficient for jetting to occur.

In Fig. 45.8, the beginning of the unbounded centre region is visible despite the wavy interface formed due to the high impact velocity. So the shape of the hump may have an effect on the jet direction and this is to be studied in order to improve bonding in the central part of the spot.

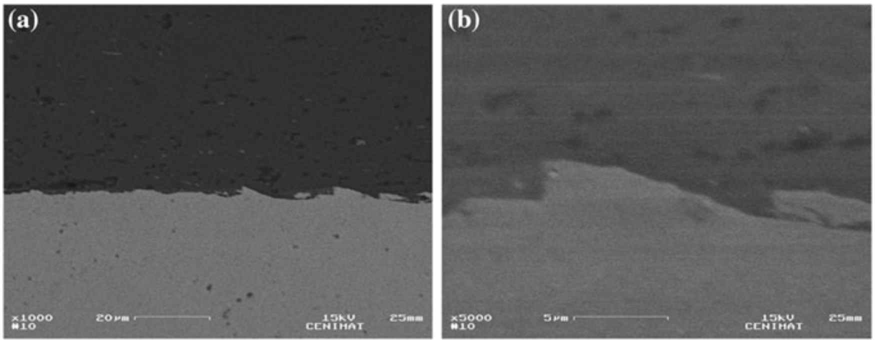
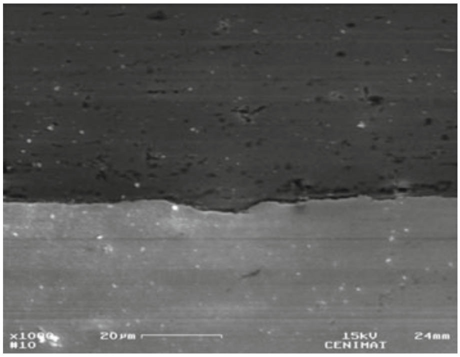


Fig. 45.7 **a** Bonded interface (backscattered electron analysis mode). **b** Detail of the previous (secondary electron analysis mode)

Fig. 45.8 Centre unbounded region



45.4 Conclusions

From this study the following can be concluded:

- MPSW was tested in thin sheet dissimilar steel/aluminium lap joint configuration.
- The spot was analyzed and it was seen that there was no bonding at the center, there are two bonded areas symmetrically located on each side of the central unbonded area. Considering the hump geometry these may be due to the absence of the jet effect in the spot center.
- In the adjacent areas the temperature and pressure were high enough to create bonding due to inter-atomic diffusion.
- From SEM analysis of the spot welds made by MPSW process, there are two different weld zones (a) flat interface, where no weld is seen and (b) weld interface with wave pockets in two opposite directions from the center of the weld (rectangular hump geometry).

- According to Al-Fe phase diagram intermetallics Fe_2Al_5 and $FeAl_3$ can form with a thickness of 0–2 μm and its distribution is discontinuous which may be due to the interlocking of intermetallics on to those wave pockets.

Acknowledgments DP and RM acknowledge Pest OE/EME/UI0667/2011 from the Portuguese Fundação para a Ciência e a Tecnologia (FCT-MEC).

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Chapter 46
Lean Services: An Approach for Supply Chains Based on the Gaps Model of Service Quality

Raul Susano, Carmen Jaca and Rogério Puga-Leal

Abstract Supply Chains (SC) encompass interfaces where several interactions occur, notably with flows of services, products and information. Services play a major role in modern economies and its provision is widespread along the supply chain. This piece of research utilizes the Gaps Model of Service Quality, which is based on the disconfirmation paradigm, and relates it with lean principles of waste from a supply chain perspective. The Gaps Model analyses several gaps that might occur within organizations, leading to discrepancies between expected service and perceived service. A methodology is proposed for assessing the internal failures contributing to each gap of the original model. A second stage includes an approach inspired on QFD's (Quality Function Deployment) matrices, envisaging a joint analysis of gap's structure and supply chain's failures, what allows computing the importance of each failure from a service quality perspective. Furthermore, these failures can be associated to lean wastes, thus providing a framework for "leanliness" assessment. A simplified example for a generic supply chain is also presented.

Keywords Service quality · Gaps model · Lean · Supply chain

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_46,

46.1 Introduction

Organizations within supply chains are facing increasing competition, which led them to act together in search for better efficiency in their processes [1]. On the other hand, it is interesting noticing that achieving process efficiency could be harder for organizations providing a larger variety of services, which frequently increases the utilization of outsourcing [2].

Performance across the interfaces of a supply chain is vital for its success. Very often, the bottlenecks occur in these interfaces, where goods, services and information are exchanged [3].

This piece of research is focused on service provision that occurs within supply chains and utilizes the Gaps Model for service quality that was originally presented by Parasuraman et al. [4]. Some adjustments have been made since then (e.g., [5, 6]) but the model's essence has been maintained throughout time.

46.2 Gaps Model and Service Quality

The frameworks that have been developed to deal with customer's perceptions of quality can be grouped into two primary categories: performance based and standards based frameworks [7]. Under such perspective, performance based frameworks specify perceived performance without any comparative referents while standards based frameworks specify "comparative" performance conceptualization of service quality, i.e., performance is compared to a standard. SERVQUAL, which is probably the most well-known model for the assessment of service quality, was originally developed as a standard based model [4, 8], where service performance was compared against a single expectation standard, the desired expectation.

According to this perspective there are two concepts playing a major role: customer expectations and customer perceptions.

As stressed by Zeithaml and Bitner [6], in a perfect world, expectations and perceptions would be identical: customers would perceive that they receive what they would and should. However, in real world, a gap usually exists between expectations and perceptions, being important to understand what contributes for such a discrepancy. According to the gaps model of service quality, there are several gaps occurring within organizations that contribute for the aforementioned discrepancy. Fig. 46.1 presents a synthetized perspective for the gaps model of service quality.

Taking into account the presented model, four factors influence customer expectations: word-of-mouth, personal needs, past experience and external communication. On the other hand, it becomes clear that organizations must act towards closing the gaps, thus promoting a better adjustment between customer expectations and perceptions. Therefore, understanding the key factors leading to each gap is a sine qua non condition for assuring adequate service levels. This piece of research focuses

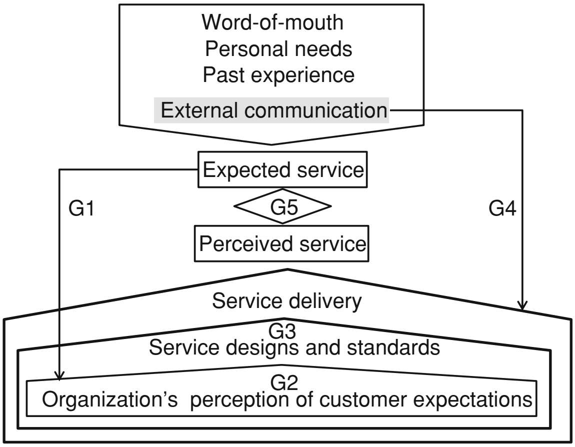

Fig. 46.1 Gaps model of service quality—simplified perspective

those factors, from a perspective of service failures within the supply chain, thus promoting a joint analysis of gap's structure and supply chain's failures.

46.3 Supply Chain's Failures from the Gaps' Model Perspective

Interactions within the supply chain constitute an opportunity for improving efficiency and efficacy among the actors, since it allows rationalization beyond their own boundaries [3].

According to Ellram et al. [9], the SSCM (Service supply chain management) is oriented towards continuous improvement of logistic operations, through the management of processes, capacities, service performance and resources along the supply chain. SSCM can be even more challenging than common SCM. In fact, since services are intangible, perishable and extremely heterogeneous, management tools become harder for implementing, what leads to an outsourcing increasing.

As mentioned above, the Gaps model establishes a gap existing between expected service and perceived service, as a consequence of other gaps occurring within organizations along the supply chain.

Although a more thoroughly analysis might be performed, adjusting those gaps to a specific supply chain, some key factors are usually associated to a generic gaps model. Those gaps are presented in Table 46.1.

Table 46.1 Key factors for the gaps

Gaps contributing for discrepancy between expected service and perceived service		
Not knowing what customer expects	Gap 1	Inadequate market research
		Weak relationship with customers
		Too many levels within organization
		Insufficient vertical communication and lack of information sharing
Not selecting the right service designs and standards	Gap 2	Service standards not oriented towards customers
		Inadequate technical specifications
		Inadequate service design
		Lack of commitment
Not delivering to service standards	Gap 3	Role's ambiguity
		Lack of adjustment between tasks and technology
		Lack of adjustment between tasks and employees
		Customers are nor aware of service characteristics
Not matching performance to standards	Gap 4	Too many promises
		Wrong management of customer expectations
		Inadequate communication among departments
		Inadequate customer support

46.4 Joint Analysis of Gap's Structure and Supply Chain's Failures

For promoting a joint analysis of gap's characteristics and supply chain failures, an approach inspired on QFD's (Quality Function Deployment) matrices was adopted [10]. The key factors were included as "rows" in the first matrix. Therefore, a systematic procedure was required for assigning importance levels to each key factor. Although other procedures could have been adopted, it was decided assigning the importance through the assessment by a panel of experts. The panel was composed by a PhD student who develops research within the supply-chain framework, as well as two researchers whose scientific activity is focused on Logistics, notably as regards supply chains. Furthermore, one of the authors started developing professional activity in a logistics operator. The approach was developed for a generic supply chain, being clear that adjustments have to be made for specific situations. Table 46.2 shows key factors along with their corresponding importance, after experts' assessment.

As regards the failures within the supply chain, a generic approach was also adopted, having the failures been assigned to six physical or organizational areas: inbound, outbound, transport, delivery, customer service and information technology.

Table 46.2 Importance of key factors

Key factors	Importance
Customers are nor aware of service characteristics	5
Wrong management of customer expectations	4.7
Inadequate technical specifications	4.7
Service standards not oriented towards customers	4.7
Too many promises	4.3
Inadequate customer support	4
Lack of commitment	4
Inadequate service design	4
Inadequate market research	4
Inadequate communication among departments	3.7
Lack of adjustment between tasks and technology	3.7
Insufficient vertical communication and lack of information sharing	3.7
Role's ambiguity	3.3
Weak relationship with customers	3.3
Lack of adjustment between tasks and employees	3
Too many levels within organization	2.7

				SCF1	SCF2	SCF3	SCF4
				Direction of improvement			
				↑	○	↓	○
KF1	Importance	3	I1	R11 (●)			
KF2		4	I2			R23(△)	
KF3		2	I3	R31(○)			
KF4		3	I4				
KF5		1	I5				
KF6		5	I6				
				IMP-SCF1	IMP-SCF2	IMP-SCF3	IMP-SCF4

Fig. 46.2 Generic matrix relating key factors and supply chain failures

A brainstorming process, along with the analysis of daily activities in a logistic operator, led to the identification of a large set of failures: inadequate package identification, wrong storage, errors in invoices, delay in expedition, etc.

At this point, a matrix can be developed, relating each failure with one or more key factors from the gaps model. As in QFD, relations can be strong (•), medium (○) or weak (△). Usually, a strong relation is weighted with 9 points, a medium relation with 3 points and a weak relation with 1 point. To illustrate the concept, a generic matrix is presented in Fig. 46.2.

In the previous matrix it is also identified which direction for improvement is associated to each failure, according to Taguchi perspective: lower the better, higher the better and nominal the best. The presented matrix supports the calculation of failure's importance from service quality perspective. The importance of supply chain failure j, would be computed as follows: $(IMP - SCF)_j = \sum_{i=1} R_{ij} \times I_i$, for instance, $(IMP - SCF)_1 = 9 \times 3 + 3 \times 2 = 32$.

This approach can be deployed to further matrices, through an approach similar to QFD. Generically, the columns from one matrix are transported as rows to the following matrix. Their importance can then be computed using an approach similar to the previously presented.

As regards the lean principles, there is some consensus as regards wastes' classification, which comprises the following categories [11]: Transport, Inventory, Motion, Waiting, Over Production, Over Processing and Defects.

These wastes can be included as new columns in a deployed matrix, where the rows are constituted by the aforementioned supply-chain failures with their corresponding importance. Hence, following the approach presented above, a relationship can be established between the wastes and the supply-chain failures. Furthermore, the importance of each waste from a supply-chain failure's perspective can easily be computed, thus providing a framework for "leanliness" assessment.

46.5 Conclusions

Looking into a supply-chain from a service perspective is a challenging approach. The gaps model of service quality is usually applied to frameworks exclusively associated to service provision. Therefore, its utilization within the framework of a supply-chain is not straightforward. Nevertheless, the authors believe that supply-chains' performance can benefit from such insights. Other approaches, such as FMEA (Failure Modes and Effects Analysis), can be very useful for analyzing failures and their consequences in supply-chains. However, the joint approach provided by the gaps model of service quality along with the matrices based in those from QFD, encompasses the potential of further deployments, thus enhancing the ability for the adoption of several perspectives, notably as regards other paradigms.

46.6 Limitations and Suggestions for Future Research

The proposed approach was developed having in mind a generic supply-chain. Further refinements and adjustments would have to be put in place for utilizing that approach in a specific supply-chain. For such a framework, beyond the participation of scientific experts, the contribution of professionals working on the chain would be vital for a successful implementation.

The deployment that was discussed, addressing the lean paradigm, can be expanded to other paradigms, such as the agile, resilient or green paradigms. These new approaches might constitute encouraging challenges for new developments. Furthermore, a better understanding of customer expectations, which were not addressed in this piece of research, can provide new perspectives into supply chains' design.

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Chapter 47
Ship Building Production in Jiangsu Province Based on DEA Efficiency Analysis

Guangming Zhang and Huayi Liu

Abstract The productivity of shipbuilding plays an important role in the transformation from a big shipbuilding province to a strong shipbuilding province of Jiangsu, which is now the largest shipbuilding province. DEA is applied when analyzing the Jiangsu province's productivity of shipbuilding both in the aspects of technology and scale in this paper, and we can get the conclusion that the excess capacity caused by over-input of personnel and material and poorly management led to the inadequate productivity about shipbuilding in Jiangsu, and the relevant countermeasures are proposed in this paper.

Keywords Jiangsu · Shipbuilding · DEA · Efficiency

47.1 Introduction

As the largest shipbuilding province in China, Jiangsu occupies absolute advantage on the number of shipbuilding, in 2009, 2010 and 2011, its shipbuilding completions accounted for the proportion of the national were 35.5, 34.5 and 36.4 %. In 2012, Jiangsu shipbuilding industry continued to maintain steady development trend, its shipbuilding completions amounted to 22.185 million dead weight tones, that is 15 % of the world's market share, and 36.8 % of the country's. Its strategic role in Jiangsu province's industrial development is becoming more and more obvious. Even though shipbuilding production capacity of Jiangsu has achieved stable development, it is insufficient in the production technology, management and utilization, and the problems of shipbuilding production's low efficiency and overcapacity are becoming increasingly prominent, due to blind expansion of investment. Lean man-

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_47,

ufacturing has become an important strategy of the development of the shipbuilding enterprises; therefore, the analysis of Jiangsu shipbuilding production's efficiency has both realistic and theoretical guiding significance.

Data envelopment analysis (DEA) is based on the concept of relative efficiency. The relative relation between the efficiency of decision making units, namely the relative effectiveness are permitted to use DEA method to estimate directly. DEA method of relative efficiency evaluation is now successfully applied in different fields of society and industry, such as city, bank,base maintenance, weapons and equipment efficiency analysis, military aircraft flight, etc., and significant results and good social reflect have been achieved. This method has also been used in the area of domestic shipbuilding efficiency research in recent years. Such papers are as Zhang [1] evaluated the technical efficiency of China's shipbuilding industry situation, Tao and Chen [2] analyzed the efficiency of shipbuilding industry in Yangtze River delta and Su [3] analysis of the working team activity responsibility cost for shipbuilding enterprise. This paper uses DEA method aiming to conduct a comprehensive evaluation of Jiangsu shipbuilding production efficiency by analyzing the production efficiency, technical efficiency and scale efficiency. And several countermeasures to improve the production efficiency are presented on the basis of analyzing the results.

47.2 The DEA Method

Wei [4] indicated that Data Envelopment Analysis, hereinafter referred to as DEA, is a nonparametric statistical method which evaluates the relative efficiency of Decision Making units (hereinafter referred to as the DMU) with the same type and multiple inputs and outputs. In order to solve the problem of finding the best production frontier, measuring DMU production point with the best front surface distance (curved section which takes on all the DMU) and obtaining the way to measure the efficiency of DMU. Charnes et al. [5] said that proposed DEA which was a new data statistic analysis method on the basis of the concept of "relative efficiency evaluation" in 1978. Zhang and Li [6] considered that his method can not only handle the problems of multiple inputs and outputs simultaneously without the restriction of index dimension, but also can be directly makes the comprehensive analysis of various qualitative indexes and quantitative indexes without data preprocessing. The CCR and BCC are two of the most representative research and application of DEA model in the theoretical system of the DEA method. Based on the analysis of Jiangsu shipbuilding production efficiency, the DEA models that this paper choose are also the CCR and BCC models. Here are the two kinds of data models:

1. The CCR Model. CCR model is on the premise of assuming the returns to the scale is a constant, that is, to increase the certain proportion of cast, the output should also be increased in the same proportion. It is used to calculate the comprehensive relative efficiency value of each decision making unit (comprehensive efficiency value including pure technical efficiency and scale efficiency). The CCR model can be expressed in Eq. (47.1).

Assume that there are n DMU, each of which DMU ($k = 1, 2, \cdots, n$) uses m kind of inputs x_{ij}, and outputs s kind of outputs y_{ir} ($x_{ij} \geq 0$, $y_{ir} \geq 0$), v_i and u_r are respectively the weights of the i_{th} input index and the r_{th} output, Hence the relative efficiency of DUM o $h_{o(u,v)}$ can be written as the following form:

$$\begin{cases} \min h_{o(u,v)} = \dfrac{\sum\limits_{r=1}^{s} u_r y_{ro}}{\sum\limits_{i=1}^{m} v_i x_{io}} \\ \text{s.t.} \begin{cases} \dfrac{\sum\limits_{r=1}^{s} u_r y_{rj}}{\sum\limits_{i=1}^{m} v_i x_{ij}} \leq 1 \\ ur, vj \geq 0, r = 1, 2, \cdots, s \\ i = 1, 2, \cdots, m, j = 1, 2, \cdots, n. \end{cases} \end{cases} \tag{47.1}$$

According to the input and output vectors of DMU, we can conclude the comprehensive efficiency of each DMU by type (1). In order to calculate conveniently, make (u, v) satisfies the $\sum_{r=1}^{s} u_r y_{ro}$, the fractional programming problem is converted into easy to deal with linear programming problem through dual operation, to discuss and make it easy for computing applications, further introduction of slack variable s^+ and the rest of the variables s^-, the above inequality constraints into equality constraints, And then be able to get the Eq. (47.2):

$$\begin{cases} \min z_o = \theta - \varepsilon \left[\sum\limits_{i=1}^{m} s_i^- + \sum\limits_{r=1}^{s} s_r^+ \right] \\ \text{s.t.} \begin{cases} \theta x_{io} - \sum\limits_{j=1}^{n} x_{ij} \lambda_j - s_r^+ = y_{ro} \\ \sum\limits_{j=1}^{n} y_{rj} \lambda_j - s_r^+ = y_{ro} \\ y_j, s_i^-, s_i^+ \geq 0. \end{cases} \end{cases} \tag{47.2}$$

Set the optimal solution of (2) are θ^*, s_r^{*+},s_r^{*-},$\lambda*$. There are:
(1) If $\theta^* < 1$, DMU_O is not DEA efficient;
(2) If $\theta^* = 1$, then DMU_O is weak DEA efficient;
(3) If $\theta^* = 1$, and $s_r^{*+} = s_r^{*-} = 0$, then DMU_0 is DEA efficient.
2. The BCC Model. Determination of technical efficiency is the CCR model under the assumption of constant scale reward of relative efficiency, but not every DMU under the fixed scale production, The size of the DMU remuneration is not static, Different periods may be in a state of increasing or decreasing, there are two reasons for the inefficiency of DMU: (1) Their configuration of input and output is not reasonable. (2) Its size is not appropriate. Thus, Banker, Charnes, Cooper adds a convexity assumption conditions $\sum_{i=1}^{n} \lambda_i = 1$ on the CCR model, to show the change scale reward, that is the BCC model.

Steps of using DEA are: Wade and Joe [7] indicated that (1) define and select the evaluation object; (2) look for relevance and Suitable input-output project, to make it easy to evaluate the relative efficiency of object; (3) apply DEA model to analysis. In this paper, the above steps are regarded as the basis of DEA analysis.

47.3 Empirical Research and Analysis

47.3.1 The Selection of Decision Making Units

DEA method can evaluates the relative effectiveness among the comparative objects. Zhao et al. [8] point out that we must choose decision making unit (DMU) correctly so as to apply the DEA method correctly and obtain scientific evaluation conclusions and useful decision information. From the experience and technology, the DEA has the following requirements of decision making units: (1) all of DMU should have the characteristics of the same category; (2) It is better that the number of DMU is greater than the total number of the input and output indicators, because it can technically rules out the internal linear correlation of input or output set.

For any decision making units, Its achievement of 100 % efficiency refers to: (1) Under the condition of existing inputs, each kind of output elements won't be able to increase unless reducing other types of output elements at the same time. (2) To achieve the output elements of the existing unless it increases other types of investment at the same time, or any kind of input elements cannot be reduced. If efficiency of a decision making unit is 100 %, it shows that the decision-making unit is relatively effective, which is referred to as the effective decision making units.

All decision making units in this text are China's major shipbuilding provinces, which are in the same type.

47.3.2 The Choice of Input and Output Index

When it comes to selecting input and output indicators, Chen and Liu [9] indicated that we should consider the following aspects: First of all, the choice of indicators can meet the requirements of evaluation, reflect the competitiveness of the evaluation objects objectively; Secondly input (output) sets with strong linear relationship between the internal index should be avoided technically; Finally the importance and availability of indicators should be considered.

The production characteristics of shipbuilding enterprises and enterprise goal are the main consideration in this text when we choose input and output project of the shipbuilding enterprises. According to the principles of unity, comparability of the data size, at the same time avoiding higher rate and correlation index, combining with the actual fact of shipbuilding industry, we can select industry staff number, major equipment (the total number of berth and dock) as inputs factors, total outputs as output factors.

Table 47.1 Relevant data list of shipbuilding industry in Jiangsu province in 2007–2011

Year	The average number of practitioners	Output
2007	43,049	4,518,829
2008	70,593	8,976,506
2009	113,862	14,090,157
2010	198,397	17,577,618
2011	228,489	20,985,626

Table 47.2 Relevant data list of major shipbuilding in 2011

Province	Annual average workers	The number of dock and berth	Annual output
Liaoning	478,662	13	5,803,402
Shanghai	28,993	33	5,788,723
Jiangsu	228,489	94	20,985,626
Zhejiang	54,311	429	7,838,776
Anhui	13,950	14	1,635,372
Fujian	14,874	3	1,274,456
Shandong	36,764	29	4,605,131
Hubei	26,135	34	2,417,143
Guangdong	42,835	25	4,142,949
Chongqing	13,477	48	1,737,970

47.3.3 The Original Data and the Corresponding Processing

We made an Analysis of the production efficiency about the main producing area of shipbuilding and Jiangsu province in China in this text. The data derive from the yearbook of China shipping industry statistics in 2007–2011 and related collected materials (Tables 47.1, 47.2).

1. Calculation process

Choosing DEAP2.1 as DEA operation platform, DEAP2.1 is free calculation software provided by Professor Celli, who is from the New England University in Australia. Using of DEAP2.1 software, we can gradually apply the CCR and BCC models in data envelopment to operate, after dealing with the data, the production efficiency, pure technical efficiency and scale efficiency can be calculated, the result of data is shown in the Tables 47.3 and 47.4.

2. Analyzing the calculation result

(1) Comparative analysis of Jiangsu province in recent five years. From Table 47.3, we can get the change of production efficiency, technical efficiency and scale efficiency of shipbuilding in Jiangsu province in 2007–2012 (as shown in Fig. 47.1). Changes can be seen from the diagram, production efficiency of the shipbuilding is mainly affected by the change of the scale efficiency, scale efficiency first increased and

Table 47.3 The DEA model calculation results of shipbuilding industry in Jiangsu province in 2002–2011

Years	Production efficiency	Technical efficiency	Scale efficiency	Scale reward
2007	0.826	1.000	0.826	↑
2008	1.000	1.000	1.000	-
2009	0.973	1.000	0.973	↓
2010	0.697	0.866	0.804	↓
2011	0.722	1.000	0.722	↓

Note "↑" means increase, "-" means keeping the same, "↓" indicates decreasing in table

Table 47.4 The DEA model calculation results of the main shipbuilding in our country in 2011

Province	Production efficiency	Technical efficiency	Scale efficiency	Scale reward
Liaoning	1.000	1.000	1.000	-
Shanghai	1.000	1.000	1.000	-
Jiangsu	0.686	1.000	0.686	↓
Zhejiang	0.723	1.000	0.723	↓
An hui	0.625	1.000	0.925	↑
Fujian	0.925	1.000	0.925	↑
Shandong	0.745	0.764	0.976	↑
Hubei	0.463	0.672	0.963	↑
Guangdong	0.647	0.672	0.963	↑
Chongqing	0.646	1.000	0.646	↑

Note "↑" means increase, "-" means keeping the same, "↓" indicates decreasing in table

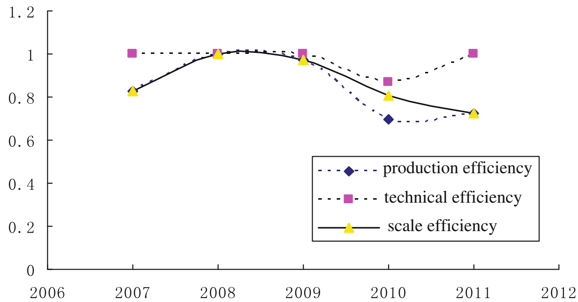

Fig. 47.1 The change of production efficiency, technical efficiency and scale efficiency of shipbuilding in Jiangsu province in 2007–2012

then decreased. And see from Table 47.3, Scale reward also fell in reducing years, this shows the capacity of shipbuilding production in Jiangsu is become excess since 2009. Demand of the ship industry was increasing in 2007, so was scale reward, enlarging the production scale will improve the production efficiency, it leads to expansion of the Shipbuilding capacity of the Jiangsu province; the reasons why the shipbuilding production efficiency to achieve effective and scale reward keeps a constant in 2008 are: In 2008, the outbreak of the financial crisis had the negative

effect on the shipping industry and leaded to the reduction of the blind production of shipbuilding industry. But due to the poor demand of market, since 2009, the new orders appear, hand-held orders have a downward trend. From Table 47.3, technical efficiency value is higher than the scale efficiency value of Jiangsu shipbuilding industry, and both of them are less than 1. On the one hand: technical inefficiency and scale inefficiency are the source of the inefficiency of the Jiangsu shipbuilding, on the other hand, the major source of production inefficiency is scale inefficient, and it can be obtained from diminishing size: Jiangsu shipbuilding industry is in a state of excess production capacity in 2010. At the same time, the enterprise management level is poorer, which is also one of the reasons for the inefficiency of Jiangsu shipbuilding industry.
(2) Comparative analysis between Jiangsu and other shipbuilding areas. The Table 47.4 shows the lateral comparison of Jiangsu shipbuilding productivity and we can see that the productivity in Jiangsu shipbuilding industry was very low relative to other shipbuilding areas in China in 2011. It only ranked sixth. From BCC model, we know that productivity equals technical efficiency plus scale efficiency, but the technical efficiency in Jiangsu was 1.000 so that we can get the information that the low productivity attributed to the low scale efficiency. In addition, the scale reward was also decreasing, so it indicates that the production capability was excess in 2011.

47.4 Conclusion, Countermeasure and Suggestion

47.4.1 Conclusion

It can be concluded from the analysis that the main reason of the shipbuilding inefficiency in Jiangsu province is scale efficiency, whose decreasing is resulted from the surplus productivity in Jiangsu shipbuilding industry. Besides, the fluctuation of technical efficiency also reveals the fact that the instability of shipbuilding management needs continuous improvement. Therefore, to enhance the competitiveness of shipbuilding industry in Jiangsu province, it not only should change the extensive expansion mode and readjust the scale of shipbuilding industry to a reasonable level, but also needs to improve the management.

47.4.2 Countermeasure and Suggestion

1. Optimizing productivity

The main reason of the shipbuilding inefficiency in Jiangsu province is enlarging the production scale blindly when this industry was thriving, which leads to the excessive capability now. Jiangsu is one of the largest provinces which build ships in China.

To becoming a competitive province, it is essential to increase productivity. That's why we must solve the problems of capacity surplus.

In first place, to solve the above problems, the government is supposed to Strengthen macro-economic control and cannot enlarge the production scale merely by expand the scale of production to increase productivity, the government should prevent the blind expansion of production scale. Besides, carrying on some special project to rectify the situation where there exist low-quality ships, cleaning up and recognizing the projects under or awaiting construction, prohibiting the illegal shipbuilding as well as repetitive construction at low level. Changing the develop pattern to make shipbuilding industry go on a sustainable development road.

What's more, it is necessary for shipbuilding to optimize the product structure. When we vigorously develop the large and ultra-large ships, it's also important to enhance the level of shipbuilding and build ships with high technology and high added value. Therefore, We should make great effort on the building of ships such as LNG, LPG, ocean engineering ships and others with high technology and added value. It is the best choice that launching the diversified operating and optimizing business structure when facing the inadequate market demand.

2. Improving the management level

The research made by the relevant department of shipbuilding industry shows that management optimization will account for 31 % of the whole increase in productivity considering the impact on the proportion of production efficiency from each factor. Obviously, there is huge profit potential underlying the enterprise internal management. To improve the management, except for coordinating the relationships among the design, process, technology, management mechanism, institution structure and production layout, it also needs to take all aspects into consideration to make them cooperate and complete each other. Only by these ways can we reach the target of improving the internal management and reducing the production cost.

Acknowledgments This research is supported by Social Sciences Foundation of Jiangsu, People's Republic of China (09EYA003).

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Chapter 48
The Substitution Effect of Trade Credit Financing in an Emerging Economy: Empirical Evidence from China

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Abstract Trade credit, together with short term bank credit, forms the main short-term financing channels for enterprises. Using the data of the Chinese listed companies during the period from 1998 to 2009, this paper verifies the substitution effect of trade credit financing on short-term bank credit in an emerging economy. This study further finds that the substitution effect of trade credit financing trade credit is relatively stronger in private owned enterprise than in state-owned enterprises, and weaker in areas with higher degree of financial development. The results indicate that in China's imperfect financial system, trade credit is particularly important for private owned enterprise' financing, while state-owned enterprises are less subjected to financing constraints. In addition, the study found that with the development of the financial market in China, the substitution effect of trade credit will decrease with the improvement of the credit allocation efficiency.

Keywords Trade credit · Bank credit · Substitution effect · State ownership · Financial development

48.1 Introduction

Trade credit is the loan relationship among enterprises due to the deferred payment or advance payment of buying goods or services. It is a kind of "spontaneous financing" coming from commodity exchange, which has the dual nature of finance and business. Trade credit gain is closely related to corporate business strategy and specific industry circumstance, which is not completely at the enterprises' will [23].

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_48,

Extensive application of trade credit makes it an important way of informal short-term financing. Some scholars e.g. Garmaise and Moskowitz [12], Guiso et al. [15] found that even in a developed financial market, informal financing channel is still important for enterprises. In the area with less developed financial market, trade credit even plays a more important role as an alternative channel of external financing [31].

The Trade credit-bank credit substitution hypothesis was first introduced by Meltzer [21]. He found that the conjecture by which credit rationing favors large firms was not established, because banks and financial institutions were not the only source of credit for small firms. He showed that during money tightening period in mid-1950s in the US, firms with relatively large cash balances increased the average length of time for which Trade credit was extended, thus favoring the firms against whom the credit restriction was said to discriminate.

Since then, there have been numerous studies about the interactions between trade credit and short term loan. Brechling and Lipsey [3], Jaffee and Modigliani [18], Jaffee [17], Herbst [16] and Duca observed in one way or another that credit-constrained firms made a larger use of trade credit when credit conditions were tighter. Using a long period data from United States. Nilsen [24] confirmed that enterprises with difficulty in obtaining bank loans would finance through trade credit. Love [20] also found international evidence for substitution effect. Using the data of the listed companies in China, Shi [29] found that there existed an alternative relation between trade credit and bank loan, which was negatively correlated with the business cycle.

However, using the data in a period from 1970 to 1990s in United States, Oliner and Rudebush [25], Gertler and Gilchrist [13] found that Meltzer's substitution effect hypothesis is not necessarily true. Some scholars even provide opposite evidence against substitution effect. Ono [26] held the opinion that banks prefer issuing loans to firms with well financial and operation conditions, and such firms are more likely to gain trusts from their suppliers, so they could receive more trade credit. Using the data from manufacturing sector of Japan, Ono [26] found evidence for a complementary relationship instead of substitutive relationship between the trade credit and short term bank loan. Moreover, Danielson and Scott [7] utilized both direct indexes (e.g. whether a firm successfully obtain a loan recently) and indirect indexes (e.g. the duration of the relation between firms and banks) to measure the level of credit constraints, and found that the the quantity of bank loans and trade credit were positively correlated. It implied that the abilities of using bank loan and trade credit were coincident. This was to say they were possibly complemented.

Using the data of Chinese listed firms, this paper investigates the substitution relationship between trade credit and bank loan, while considering the ownership structure of the firms and the different degree of financial development in different areas of China. Specifically, we want to answer the following questions: Can trade credit significantly serve as a substitute of bank loan in China? Is there any difference between stated-owned enterprises and private enterprises in terms of the interaction relationship between short term bank loan and trade credit? Last but not least, how will firms' dependence on trade credit financing change with the development of financial market in China?

48.2 Theoretical Analysis and Hypothesis

The hypothesis that trade credit can serve as a substitute of bank loan was first suggested by Meltzer [21] and then further supported by the theory of credit redistribution and comparative advantage of financing with trade credit. The theory of credit redistribution suggests that the companies with easier access to credit from formal institutions will redistribute their bank loan in forms of trade credit to the firms who can hardly gain credit from banks [24]. In this case, corporations that face difficulties in obtaining bank credit will choose trade credit as an alternative channel of financing.

Compared with financial institutions such as banks, corporations have comparative advantages in credit allocation. That's why credit redistribution prefers non-financial enterprises Schwartz [28]. Firstly, comparing to the banks, the suppliers of trade credit have an advantage in obtaining information about the credit receiver. The business relationship with the customers makes the suppliers have more opportunities to get in touch with their customers, obtain information of their production and operating conditions timely and make adjustment for credit extension with such information [4, 30]. Of course, banks can search for such information as well, but since the corporations is unwilling to reveal their undesirable operating information to banks, the cost and deviation of getting information are higher than the suppliers [11]. Secondly, the suppliers of trade credit have an advantage in risk control. When the operating and credit conditions of the customers deteriorate and the possibility of paying back the credit falls, the suppliers can cut off the supply of raw materials to threaten their customers and ask for credit repaying [6, 32]. Banks, on the contrary, have less effective threat and control on the customers. The banks' influence on the production and business activities of firms in short term is quite limited if not none, when the banks allege that they will cut off the credit supply in future. Thirdly, the suppliers of trade credit have an advantage in retrieving property after the contract violation. Once a credit contract is forcefully suspended due to the customers' business failure, suppliers can resell the materials or productions in a lower price to their other existed partners Mian and Smith [11, 19, 22]. The disposal cost of the assets is generally higher for the banks because of their lack of information on the companies.

Furthermore, the information asymmetry problems in the market, such as adverse selection and moral hazard, may cause credit rationing. In the case of credit rationing, some enterprises will fail to obtain bank credit even if they are willing to pay higher interest rates than the market level, and thus resort to trade credit as a substitute regardless of its higher cost.

As an emerging market, the development of China's financial market is greatly inferior to the developed ones in U.S. or Europe. The banking system in China led by big-four state-owned commercial banks are heavily criticized for its inefficiency in capital allocation [1], leaving a large number of enterprises, especially the small and medium sized private firms in financial constraints. Relative to bank loan, the trade credit among enterprise have comparative advantages mentioned above and are widely used in firms' short-term financing as a substitute for bank loan. Therefore, we make the following hypothesis:

Hypothesis 1 Trade credit serves as a substitute of bank loan in China, i.e., the firms with less bank loan will significantly obtain more trade credit financing.

State ownership still accounts for a large proportion in China nowadays. State-owned enterprises bare a lot of social burden for the government and have motivations to ask the government for different kinds of compensations and privileges, such as credit offers, tax benefits, legal protection and industry access, etc. [8]. When state-owned enterprises fall into financial distress due to poor operation and management, the government may provide support to help them solve out the problem when it's necessary, which is equivalent to providing implicit guarantees. As a result, banks are still more inclined to provide credit to the state-owned enterprises instead of private ones, for the state-owned enterprises are less likely to default under the government's implicit guarantees.

Furthermore, the four major state-owned banks lead the financial markets of China. These banks possess more than 70 % of the credit funds and dominate the credit market. The state owned banks have a natural preference to allocate credit to state owner enterprises since they are both controlled by the government. As a result, credit resources are disproportionately allocated to state-owned enterprises, whereas private firms find it difficult to obtain support from banks [1]. A great deal of literature has revealed obvious credit discrimination against private firms in China [2, 14], which makes the private enterprises encounter serious financing constraints [5]. Nevertheless, Cull and Xu [5] reminds that the state-owned corporations with low efficiency will redistribute their bank credit to those efficient non-state-owned enterprises in forms of trade credit. Therefore, we should expect that the substitution effect of trade credit financing will be more significant among private owned enterprises instead of state owned ones, which yields the following hypothesis:

Hypothesis 2 The substitution effect of trade credit financing is more significant among private owned enterprises than among state owned ones.

The process of marketization and reform in financial system in China has made a great progress since 1978. However, due to different resource endowments, geographic locations and regional policies, marketization and the development of financial markets in different regions varies. Comparing to the provinces with lower degree of financial development, those with more developed financial system grant the local firms with easier access to bank loans [34], which will relieve the financing constraints of the local firms and thus their demand for trade credit. As mentioned in the analysis for Hypothesis H1, the difficult access to back credit due to credit rationing under information asymmetry, and the comparative advantages of trade credit financing are key reasons for the substitution effect of trade credit on bank credit. With the development of financial markets, the information asymmetry and credit rationing problem in formal credit market will be alleviated, and the comparative advantage of trade credit will be lower, and thus the substitution effect of trade credit financing tend to decrease. According to the analysis above, we make the hypothesis below:

Hypothesis 3 In areas with higher degree of financial market development, the substitution effect of trade credit financing is weaker.

48.3 Data and Model

48.3.1 Data and Variables

The original sample of this paper consists of all non-financial A-share listed firms in China from 1998 to 2009 to test the hypotheses above. We omitted the observations that satisfy any one of the following conditions:

1. The banks and other financial firms;
2. The companies whose financial data is missing for five consecutive years during 1998–2009;
3. The Special Treated (ST) companies. Based on the Industry Classification Standard set by China Securities Regulatory Commission, we classified the firms into 22 industry categories, where the manufacturing industry is classified according to the secondary classification code.

Following the mainstream research in this field [10, 27], this paper uses the ratio of accounts payable to total assets as the proxy for trade credit financing (TC) used by the firm, i.e., the dependent variable of our empirical models. The main explanatory variable is short term bank credit (SBC) which is measured by the ratio of a firm's short-term borrowings from banks to its total asset. Then, the coefficient in front of the variable of short term bank credit can indicate whether there is an substitution relationship between trade credit and bank credit as well as the strength of the substitution effect. We use the dummy variable whether firms' ultimate controller is the state owned as the proxy for state ownership (STATE). The indexes for financial market development of different provinces are from the Report of regional marketization Index in China (1997–2007) by Fan et al. [9]. We mainly use the index of financial market development (FDV) in the report.

Other variables include profitability, size, leverage, inventory turnover rate, current asset turnover rate, the interest rate of the borrowings from banks, and the liquidity ratio of a firm. Taking into account the influence of regional differences on firms' operating activities, we also include province dummies. Finally, we include industry dummies (INDUSTRY) and year dummies (YEAR) to control the fixed effects of different industries and time periods. We delete the samples that have missing data in the above key variables, and finally got 10101 observations. The definitions of our variables and their summary statistics are shown below in Table 48.1.

48.3.2 Regression Model

In order to test the substitution relationship between trade credit and short term bank credit, our basic regression model is as below:
(1) Where TC is the variable of trade credit financing, which is measured by the ratio of accounts payable to total assets. SBC is the ratio of short-term bank loan to total

Table 48.1 List of variables and summary statistics

Variable	Definition	Mean	Std. Dev.	Min	Max
TC	Trade credit, accounts payable/total assets	0.077	0.06	0	0.693
SBC	Short-term bank credit/total assets	0.158	0.12	0	1.506
SOE	1 if state owned, 0 otherwise	0.710	0.46	0	1
PROFIT	Profitability, net profit /sales revenue	0.071	0.96	−0.481	0.441
SIZE	Natural logarithm of total assets	21.297	0.18	12.314	27.488
LEV	Leverage, total debts/total assets	0.475	0.15	0.033	3.331
Iturnover	Inventory turnover rate, cost of goods sold/average inventory	7.427	10.78	0.255	55.824
Aturnover	Current asset turnover rate, main business net income/average current assets	1.471	1.06	0.192	4.773
FDV	The index for financial market development by Fan and Wang	7.22	2.35	0	11.71
LiquidR	Liquidity ratio, current assets/current liabilities	1.704	1.91	0.001	55.741
Intr	Interest rate, interest expenses/total borrowings from banks	0.053	0.05	0.015	0.245

assets. X are a set of control variables including size, profitability, financial leverage, Inventory turnover rate, current asset turnover rate, and state ownership. We also add a year dummy and an industry dummy to control the fixed impacts of macroeconomic fluctuation and different industries. The coefficient indicates whether there is a substitution relationship between trade credit and bank credit.

However, it should be noted that the explanatory variable, bank credit, is not exogenously given, but may be affected by other factors. Besides of the control variables included in Model (1), there might be some other omitted variables affecting access to trade credit and bank credit simultaneously, leading to a endogeneity bias.

To solve the endogeneity problem, we further use a two-step least square (2SLS) regression model with instrumental variables for short term bank credit. Since a firm's access to short term bank credit mainly depends on its short term repaying ability while the firm's access to trade credit depends more on its operation performance, we can use the firm's repaying ability, measured by the liquidity ratio (LiquidR), as the instrumental variable of short term Bank credit [29]. In addition, the interest rate charged on the bank credit (Intr) is also a nice instrumental variable, since it is closely related to the quantity of short term bank credit but has no direct effect on the access to trade credit. Therefore, in the first step, we use short term bank credit as the dependent variable, and run the regression as follows:
(2) Where Intr and LiquidR represent the instrumental variables, interest rate and liquidity ratio respectively. X includes the same set of control variables as Model (1), and represent the year and industry dummies respectively.

Table 48.2 The relationship between bank credit and trade credit

	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS
SBC	−0.124[a]	−0.267[a]	−0.123[a]	−0.268[a]
	(−24.75)	(−5.01)	(−24.59)	(−5.05)
Lev	0.131[a]	0.179[a]	0.131[a]	0.179[a]
	(39.39)	(9.55)	(39.51)	(9.58)
Iturnover	−0.000[a]	−0.000[a]	−0.000[a]	−0.000[a]
	(−3.10)	(−2.55)	(−3.07)	(−2.55)
Aturnover	0.016[a]	0.177[a]	0.016[a]	0.018[a]
	(26.26)	(12.81)	(25.90)	(12.58)
Profit	−0.024[a]	−0.030[a]	−0.023[a]	−0.028[b]
	(−6.19)	(−2.70)	(−5.79)	(−2.53)
Size	−0.003[a]	−0.008[a]	−0.003[a]	−0.008[a]
	(−4.79)	(−5.03)	(−5.56)	(−5.31)
SOE			0.006[a]	0.005[a]
			(5.29)	(1.99)
Industry dummies	Controlled	Controlled	Controlled	Controlled
Year dummies	Controlled	Controlled	Controlled	Controlled
N	10101	10101	10101	10101
R2	0.399	0.381	0.401	0.381

Note The *t* statistics were computed using the robust standard errors clustered at the firm level and are shown in parentheses. [a] $p < 0.001$. [b] $p < 0.05$. [c] $p < 0.01$

Then we run the second step regression by replacing the variable of SBC in Model (1) with the fitted value of the first-step regression in Model (2). Again, the coefficient in front of the new SBC variable indicates whether there is a substitution relationship between short term bank credit and trade credit.

To investigate the effect of state ownership and financial market development on the relationship between trade credit and bank credit, we will further add the interaction term between state ownership and short term bank credit (SOE × SBC), and the interaction term between index of financial market development and short term bank credit (FDV × SBC) into Model (1).

48.4 Empirical Results

The baseline results of OLS and 2SLS regressions are shown in Table 48.2. Either the OLS regression results or the 2SLS regression results in Table 48.2 show that relationship between trade credit and bank credit are significant and negative after controlling the effect of other variables such as firm size, financial leverage, profitability, inventory turnover rate, current asset turnover rate, state ownership as well the industry and year dummies. These results verify our Hypothesis 1: trade credit

Table 48.3 The effect of state ownership and financial market development on the relationship between bank credit and trade credit

	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS
SBC	−0.127[a]	−0.390[a]	−0.080[a]	−1.950[b]
	(−17.13)	(−3.75)	(−5.73)	(−2.28)
Lev	0.133[a]	0.180[a]	0.132[a]	0.183[a]
	(40.49)	(10.06)	(40.35)	(8.22)
Iturnover	−0.000[a]	−0.000[a]	−0.000[a]	–
	(−3.14)	(−2.70)	(−3.30)	–
Aturnover	0.016[a]	0.018[a]	0.015[a]	0.015[a]
	(27.02)	(12.59)	(25.91)	(7.08)
Profit	−0.024[a]	−0.226[b]	−0.023[a]	−0.045[b]
	(−6.11)	(−2.11)	(−5.93)	(−2.41)
Size	−0.003[a]	−0.009[a]	−0.003[a]	−0.008[a]
	(−4.98)	(−5.43)	(−6.26)	(−4.51)
SOE	0.005[b]	−0.027[b]	0.006[a]	0.010[b]
	(2.64)	(−1.88)	(5.41)	(2.63)
SOESBC	0.002	0.185[b]		
	(0.30)	(2.17)		
FDV			−0.121[b]	−0.266[b]
			(−0.68)	(−1.96)
FDVSBC			0.113[c]	0.183[b]
			(1.77)	(2.10)
Industry dummies	Controlled	Controlled	Controlled	Controlled
Year dummies	Controlled	Controlled	Controlled	Controlled
N	10732	10101	10732	10101
R2	0.398	0.372	0.400	0.348

Note The *t* statistics were computed using the robust standard errors clustered at the firm level and are shown in parentheses. [a]$p < 0.001$. [b]$p < 0.05$. [c]$p < 0.01$

can serve as a substitute of short term bank loan, i.e., the firms with less short bank loan will significantly obtain more trade credit financing.

We can also observe in Table 48.2 that the state ownership (SOE) has a significant and positive effect on access to trade credit. The significance level is 1 % in OLS regression and 5 % in 2SLS regression. Therefore, the state owned enterprises have an advantage in obtaining trade credit financing, comparing to the non-state owned ones. This result indicates that the government's implicit guarantee on SOE can not only facilitate its access to bank credit, but also ease trade credit financing. This result is consistent with Ying et al. [33].

Based on the baseline results, we continue to add the cross term of state ownership and short term bank credit (SOE $\times$ SBC) and the cross term of local financial market development and short term bank credit (FDV $\times$ SBC) into regressions, to test the effect of state ownership and financial market development on the relationship between short term bank credit and trade credit. The results are shown in Table 48.3.

Although the coefficient on the cross term SOE × SBC is not significant in the OLS regression shown in column (1), it is positive and significant at 5 % in the 2SLS regression shown in column (2). The positive coefficient on SOE × SBC shows that the substitution effect of trade credit is weaker in state-owned enterprises but stronger among non-state-owned enterprises, which is consistent with our Hypothesis H2. According to earlier research (e.g Danielson and Scott [7]), the the strength of substitution relationship between trade credit and bank loans could reflect the degree of credit rationing and credit constraints. As mentioned in our theoretical analysis, the non-state-owned corporations are more likely to be subject to the credit rationing or constraints, and thus will depend more on trade credit as an alternative channel of financing, leading to a stronger substitution effect.

It is also shown in column (3) and (4) of Table 48.3 that the coefficient on the cross term (FDV × SBC) is significant and positive using either OLS or 2SLS regression. This result verifies that in areas with higher degree of financial development, the substitution relationship between short term bank credit and trade credit is weaker. It is not hard to understand this result. In regions with more developed financial markets, firms have easier access to bank credit, and thus depend less on trade credit, leading to weaker substitution effect of trade credit. Thus, Hypothesis 3 is also verified.

48.5 Conclusions

Using the data of non-financial listed firms in China, this paper empirically tests the interactive relationship between trade credit and short term bank credit. Furthermore, we also investigate the effect of state ownership and financial market development on the relationship between trade credit and short term bank credit. it is found in this paper that firms with less bank credit will significantly obtain more trade credit financing in China, i.e., the trade credit can serve as a substitute of bank credit when a firm is faced with credit constraints.

Further analysis in this paper shows that the the substitution effect of trade credit financing is more significant among private owned enterprises than among state owned ones. This result provides new evidence for the proposition that the private owned enterprises in China have more difficult access to formal credit market than state owned enterprises, and thus depend more on trade credit as an alternative financing channel.

It is also shown in this paper that the degree of local financial market development has a significant influence in the substitution relationship between trade credit and short term bank credit. In areas with higher degree of financial development, the substitution relationship between short term bank credit and trade credit is weaker. This is probably because in regions with more developed financial markets, firms have easier access to bank credit, and thus depend less on trade credit, leading to weaker substitution effect of trade credit.

The findings in this paper indicate that under China's current imperfect financial market system, trade credit is particularly important for private owned enterprise' financing, while state-owned enterprises' are less subjected to financing constraints. In addition, with the development of the financial market in China, the substitution effect of trade credit will decrease with the improvement of the bank credit allocation efficiency.

Acknowledgments The authors would like to acknowledge the financial support from the National Science Foundation of China (NSFC71373167; NSFC71003108), the social science research fund of Sichuan University (skqy201312), and the Fundamental Research Funds for the Central Universities (Excellent Young Scholars Research program in Sichuan University, 2013SCU04A32).

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Chapter 49
Inquiring into the Economic Structural Breakpoints and Postwar U.S. Business Cycle

Junrong Liu and Zhiming Feng

Abstract The article is dedicated to inquiring U.S. postwar economic structural breakpoints and the changes in its business cycle covering the period 1947–2011. By empirical analysis, post-war U.S. economic structural breakpoints are identified, based on which the U.S business cycle is explored, mainly into the its evolution and different characteristics in different time periods.

Keywords Breakpoints · Business cycle · Evolution

49.1 Introduction

After World War II, with many social, technological and economic changes, many scholars believed, that the mutations would inevitably be reflected in the economic fluctuation patterns [1, 3, 11]. In fact, some scholars have found that the fluctuation patterns of the postwar U.S. Economy are continuously changing [2, 4, 5, 7, 13]. Based on this theme, the article is devoted to a study over the postwar economic structural breakpoints and the changes in the U.S. business cycle covering the period 1947–2011. This research paper focuses on examining into the evolution course and different characteristics of U.S. economic fluctuation over the periods. And the U.S. GDP time series data except otherwise specified are from Federal Reserve Bank of St. Louis website database. The data presented is seasonally adjusted.

The postwar economic gradual changes lead to structural changes in economic indicators, herein GDP, forming some structural breaks [6, 9, 14]. Therefore, it is of necessity to identify structural breakpoints in U.S. gross domestic products (GDP) time series. Based on the break points, the period 1947–2011 has been identified, and the economic cyclical patterns are analyzed and generalized in this research paper.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_49,

Test methods for structural breakpoints identification fall into many typologies. Such as Chow's, Perron's, Zivot and Andrew's, Lee's and so forth. Chow's test is used to determine whether a given point is a structural break point, which cannot scan out the unknown break points. For unknown break points, Perron firstly constructed an Augmented Dickey-Fuller (ADF) test model with structural break items. But, this model has a flaw: the exact location of the occurrence of a structural break should be identified in advance. As Christiano pointed out, the ADF test model is likely to lead to excessive over-rejection of unit root test against the null hypothesis.

Zivot and Andrew proposed a structural-break-root test method, which predicts break points, as those embedded in the structure of the data series, without prior location. Thus, Zivot and Andrew modified Perron's model, took the breakpoint estimation of endogeneity, and presented unconditional unit root test with breakpoints. Lumsdaine broadened the scope of the identification of the single breakpoint test and obtained a two breakpoints test (LP Test). Lee et al. further proposed a more robust Minimal Lagrangian Test for dual structural breakpoint identification.

Bai and Perron put forward a method that employs statistics in determining the breakpoint, which can justify the identifying economic structural breakpoints, while it also meets multiple-breakpoint-identification requirements.

This article is based on ARMAX models and Bai's and Perron's method, to identify the structural breakpoint of the U.S. GDP from 1947Q4-2011Q4.

Let the linear model have "m" number of structural breaks with "T" as its length.

$$\begin{aligned}
y_t &= x_t'\beta + z_t'\delta_1 + u_t, t = 1, 2, \cdots, T_1,\\
y_t &= x_t'\beta + z_t'\delta_2 + u_t, t = T_1 + 1, T_2 + 2, \cdots, T_1 + T_2,\\
&\cdots\\
y_t &= x_t'\beta + z_t'\delta_{m+1} + u_t, t = T_m + 1, T_m + 2, \cdots, T.
\end{aligned}$$

These can be rewritten in matrix form as follows: $Y = X\beta + \bar{Z}\delta + U$.

Given the certified breakpoints $T_1, T_2, \cdots, T_m$, the least squares method can be applied to estimate coefficients β, δ. These coefficients β, δ are valid, when they are inserted into the following formula: $S_T(T_1, T_2, \cdots, T_m) = \min(Y - X\beta - \bar{Z}\delta)$.

We utilize Bai's statistics $\sup F_\tau(l+1|l)$ in identifying the number of breaks. And Bai's statistics can be expressed by the equation as fellows:

$$\sup F_\tau(l+1|l) = \{S_T(\hat{T}_1, \cdots, \hat{T}_l) - \min_{1\le i\le l+1} \inf_{\tau\in\Lambda_{i,\eta}} S_T(\hat{T}_1, \cdots, \hat{T}_{i-1}, \tau, \hat{T}_i, \cdots, \hat{T}_l)\}/\hat{\sigma}^2,$$

where $\Lambda_{i,\eta} = \{\tau; \hat{T}_{i-1} + (\hat{T}_i - \hat{T}_{i-1})\eta \le \tau \le \hat{T}_i - (\hat{T}_i - \hat{T}_{i-1})\eta\}$,

Let, U.S. GDP be denoted as logarithmic values: $y(t)$, and let $y(t)$ be subject to ARMAX (R, M) model with m structural-breakpoints, then we get the following:

$$y(t) = c_1 + b_1 t + \sum_{j=1}^{R} \phi_{1j} y(t-i) + \sum_{j=1}^{M} \theta_{1j}\varepsilon_1(t-j) - \varepsilon_1(t), t = 1, 2, \cdots, T_1,$$

$$y(t) = c_2 + b_2 t + \sum_{j=1}^{R} \phi_{2j} y(t-i) + \sum_{j=1}^{M} \theta_{2j} \varepsilon_2(t-j) - \varepsilon_2(t), t = T_1+1, T_2+2, \cdots, T_1+T_2,$$

$$\cdots$$

$$y(t) = c_{m+1} + b_{m+1} t + \sum_{j=1}^{R} \phi_{(m+1)j} y(t-i) + \sum_{j=1}^{M} \theta_{(m+1)j} \varepsilon_{m+1}(t-j) - \varepsilon_2(t),$$

$$t = T_m+1, T_m+2, \cdots, T,$$

where $\{\phi_{ij}\}$ is auto-regression coefficient and $\{\theta_{ij}\}$ is the moving average coefficient.

Using Matlab software, R, M were calculated from 0–4, and thus the breaks at $T_1 = 118, T_2 = 170$ are located. Furthermore, we obtained the coefficients, with residual normality for each time interval.

For $1 \le t \le T_1$, a model can be drawn: $y(t) = 4.4777 + 0.0137t + 0.0207y(t-1) + 0.1214y(t-2) - 0.0049y(t-3) + 0.0429y(t-4) + 0.8876\varepsilon(t-1) + \varepsilon(t), t = 1, 2, \cdots, T_1$, where residual $e(t)$ is white noise, and the roots of the characteristic polynomial $(x^4 - 0.0207x^3 - 0.1214x^2 + 0.0049x - 0.0429)$ of auto-regressive part are -0.5250, 0.5269, $0.0094 + 0.3938i$, $0.0094 - 0.3938i$, with the Eigen modulo value is less than 1.0. And the characteristic polynomial roots of sliding regressive part is -0.8876, and the modulus is less than 1.0 as well.

When $T_1+1 \le t \le T_2$, a model can be drawn $y(t) = 5.7652 + 0.0207t + 0.0669y(t-1) + 0.0031y(t-2) + 0.0060y(t-3) - 0.1468y(t-4) + \varepsilon(t), t = T_1+1, T_2+2, \cdots, T_2$, where residual $e(t)$ proves to be white noise by test, the characteristic polynomial $(x^4 - 0.0669x^3 - 0.0031x^2 - 0.0060x + 0.1468)$ of auto-regressive part are $0.4557 + 0.4322i$, $0.4557 - 0.4322i$, $-0.4223 + 0.4402i$, $-0.4223 - 0.4402i$, with the Eigenvalue modulo is less than 1.0.

When $T_2+1 \le t \le T$, a model can be drawn: $y(t) = 5.0062 + 0.0092t + 0.2797y(t-1 + 0.0285y(t-2) + 0.0072y(t-3) - 0.0729y(t-4) + \varepsilon(t), t = T_2+1, T_2+2, \cdots, T$, where residual $e(t)$ is tested as white noise, and the characteristic polynomial $(x^4 - 0.2797x^3 - 0.0285x^2 - 0.0072x + 0.0729)$ of auto-regressive part are $0.4558 + 0.3330i$, $0.4558 - 0.3330i$, $-0.3159 + 0.3592i$, $-0.3159 - 0.3592i$, with the eigenvalue modulo less than 1.0.

The results of the tests above show that the U.S. economic GDP series has two breakpoints at 1976 and 1989 respectively, which is different from certain academic findings, who found the U.S. economic structural breakpoint existing at 1983–1984 [6].

Factually, U.S. GDP average growth rate is 1.37 % from 1947 to 1976, and that from 1977 to 1989 is 2.07 %, while that from 1990 to 2011 the growth rate is only 0.92 %, which is quite different from each period, which proves the existence of the break points (Fig. 49.1).

Based on the findings above, the postwar U.S. economy can be divided into three periods 1947–1976, 1977–1989 and 1989–2011. The parts below are dedicated to analyzing economic fluctuation changes in these three periods and hence these fluctuations characterize the U.S. economic cycle.

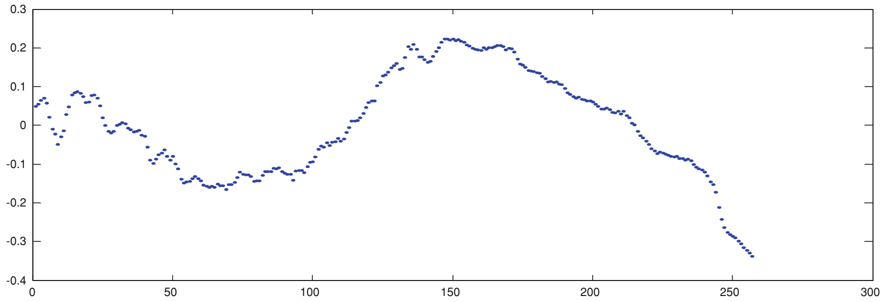

Fig. 49.1 Changes in U.S. economic growth trend (*data resource* http://www.research.stlouisfed.org/fred2/series/GDPC1)

49.2 Cycle Fluctuation Spectrum Analysis and Comparison

1. The Overall Spectral Analysis: 1947–2011 U.S. GDP Growth Rate Fluctuation Analysis

Let $\{y(t)\}$ a stationary random series $ARMA(p, q)$, that is $y(t) = a_0 + \sum_{i=1}^{p} a_i y(t-i) + \sum_{i=1}^{q} b_i \varepsilon(t-i) + \varepsilon(t)$, where a_i, b_j are constants, and $\{\varepsilon(t)\}$ is normal white noise with density distribution of $N(0, \sigma^2)$. Denoting the autocorrelation function of $\{y(t)\}$ as $R(k)$, thus the function can be written as the integral of a non-negative function $f(\omega)$ as follows: $R(k) = \frac{1}{2\pi} \int_{-\pi}^{\pi} f(\omega) e^{\sqrt{-1}k\omega} d\omega$, where function $f(\omega)$ is the spectral density of {y(t)}, and thus $f(\omega) = \sum_k R(k) e^{-\sqrt{-1}k\omega}$.

To the series $\{y(t)\}$ of $ARMA(p, q)$, its spectral density function $f(\omega)$ is:

$$f(\omega) = \sigma^2 \frac{\left| 1 + \sum_{k=1}^{q} b_k e^{-\sqrt{-1}k\omega} \right|^2}{\left| 1 - \sum_{k=1}^{p} a_k e^{-\sqrt{-1}k\omega} \right|}.$$

Take the natural logarithm of U.S. GDP in 1947–2011. The growth rate is the gap between the preceding item and the consequent item. And through AIC and BIC test on $\{y(t)\}$, the approximation orders of p, q can be drawn, then by the means of the scanning test with programming, $p = 10$, $q = 19$, and $f(\omega)$ (the spectral density of $\{y(t)\}$) graphed as Fig. 49.2, with two maxima $\frac{2\pi}{28.3186}$ and $\frac{2\pi}{12.5490}$, indicating that $\{y(t)\}$) has two cycles with wavelengths 12.5490 and 28.3186 quarters respectively.

Now presume:

$$y(t) = a_0 + a_1 \cos \frac{2\pi t}{T_1} + b_1 \cos \frac{2\pi t}{T_1} + a_2 \cos \frac{2\pi t}{T_2} + b_2 \cos \frac{2\pi t}{T_2} + \varepsilon(t),$$

where T_1, T_2 are cycle length, and $\varepsilon(t)$ is normal white noise. By curve fitting and normalizing residuals, the following equation is obtained:

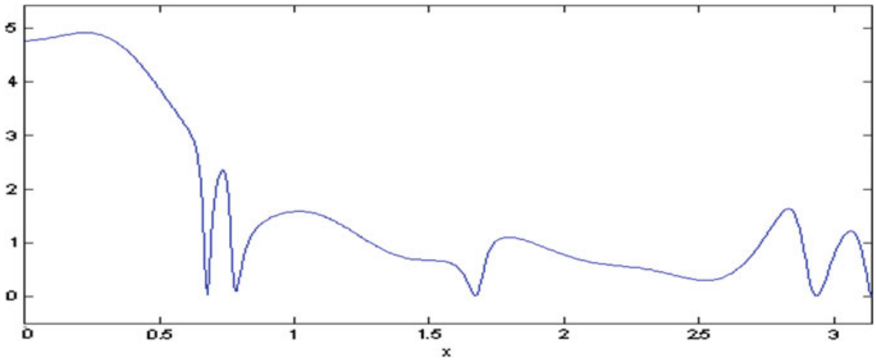

Fig. 49.2 U.S. economic cycle spectral density of 1947 (IV)–2011 (IV) (*data resource* http://www.re-search.stlouisfed.org/fred2/series/GDPC1)

$$y(t) = 0.0160 - 0.0012 \sin \frac{2\pi t}{11.9936} + 0.0023 \cos \frac{2\pi t}{11.9936} - 0.0016 \sin \frac{2\pi t}{31.1889} + 0.0013 \cos \frac{2\pi t}{31.1889} + \varepsilon(t).$$

The equation indicates that there are two cycles with wavelength 12.5490 quarters (3 years approximately) and 28.3186 quarters (7.8 years approximately) respectively. Therefore, it can be shown that, from 1947 to 2011, there is a presence of 28–31 quarter cycles (Juglar Cycle) and 12–12.5 quarter cycles (Kitchin Cycle). According to these estimates, we can further predict the amplitude of the two kinds of cycles as follows:

Kitchin Cycle's amplitude is: $\sqrt{a_1^2 + b_1^2} = \sqrt{0.00000673} = 0.0025942244.$

Juglar Cycle's amplitude is: $\sqrt{a_2^2 + b_2^2} = \sqrt{0.00000425} = 0.0020615528.$

2. Periodic Spectral Analyses and Comparison

Using the methods shown above, this section analyzes U.S business cycles, in the three distinct periods, based on the two breakpoints identified above and then comparing them.

Under MATLAB 7.10 environment, the business cycle's spectral density maps and test results of the three periods are demonstrated as follows (See Fig. 49.3 and Table 49.1). With the tests above, we obtained U.S. postwar wavelength and amplitude of business cycles. (see Table 49.2) of 1947 (IV)–2011 (IV). From Table 49.2, we can see that the wavelength of the postwar U.S. Kitchin Cycles is 11.9936 quarters (about 3 years), with an amplitude of 0.002594224. While that of Juglar Cycles is 28.58 quarterly (about 7 years),with an amplitude of 0.002061553.

According to the structural breakpoints identified, the U.S. economy is divided into three time sections: 1947 (IV)–1976 (IV), 1977 (I)–1989 (IV) and 1990 (I)–2011 (IV). Based on the wavelength and amplitude of the business cycles in these

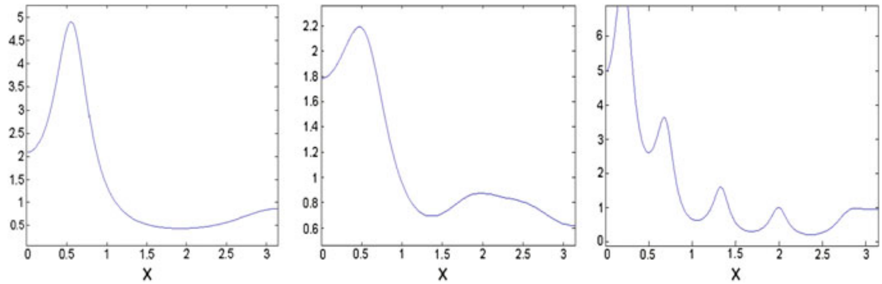

Fig. 49.3 U.S. business cycle spectral density

Table 49.1 U.S. postwar business cycle three-periods results of spectral analysis

Periods	h	q	p	$\|T\|_a$	$\|T\|_r$	$\{\varepsilon(t)\}$	Cycle length (quarters)	Amplitude
1947–1976	0	1	3	< 1	< 1	White noise	11.3–11.5	0.00259
							28.58*	0.002924
1977–1989	0	1	3	< 1	< 1	White noise	10–13	0.00578
							18.37	0.00515
1990–2011	0	1	3	< 1	< 1	White noise	9–14	0.00311
							26–31	0.00312

$|T|_a$ is the eigenvalues modulo of the characteristic polynomial root of Auto-regressive part; $|T|_r$ is the Eigenvalues modulo of the characteristic polynomial roots of sliding regressive part; $\{\varepsilon(t)\}$ is the residuals. $*$ the data obtained with Matlab cftool processes

Table 49.2 The wavelength and amplitude of U.S. business cycle [1947 (IV)–2011 (IV)]

Periods	Kitchin cycle			Juglar cycles		
	Wave length[a]	Amplitude	Trends	Wave length[a]	Amplitude	Trends
1947(IV)–2011(IV)	11–12	0.002594224		28–31	0.00206155	
1947(IV)–1976(IV)	11.3–11.5	0.004542026	↓ / ↑	28.58	0.00292462	↓ / ↑
1977(I)–1989(IV)	10–13	0.005787055	↓ / ↑	18.37	0.00514958	↓ / ↑
1990(I)–2011(IV)	9–14	0.003106445	↓ / ↑	26–31	0.00311899	↓ / ↑

↑ means elongating or signifying; ↓ means shortening or waning. a: quarters

three periods, we find that postwar U.S. business cycle-length went through course from elongating to shortening and then from shortening to elongating. And postwar U.S business cycles have also experienced varying from waning to waxing and from waxing to waning, in amplitude. Generally, the postwar U.S. Kitchin Cycles have shown an elongation trend, while Juglar Cycles show contraction trends.

Based on the above analyses, we found that there is a presence of 2–3 year Kitchin Cycles and 6–9 year Juglar Cycles, in U.S. postwar economy. As to the wavelength, the Kitchin Cycles experienced an elongating-shortening-elongating process, but largely, Kitchin Cycles have a trend towards elongation. And the amplitude change of Kitchin Cycles presents a trend of waning?Cwaxing-waning cycles. For Juglar Cycles, the wavelength of the postwar U.S. economy followed the same trend as the

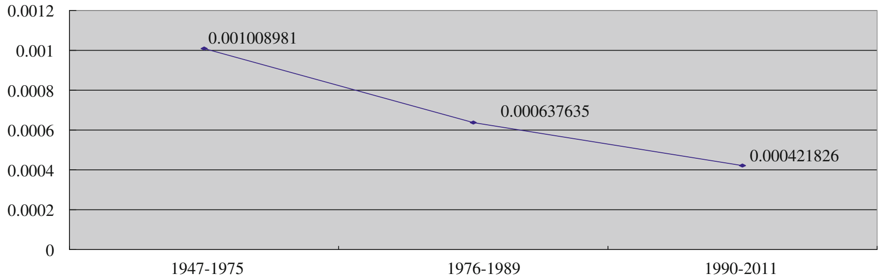

Fig. 49.4 U.S. economic growth variance comparison of the postwar three sections (*data resource* http://www.research.stlouisfed.org/fred2/series/GDPC1)

Table 49.3 The wavelength and amplitude of U.S. business cycle [1945(IV)–2011(I)]

Date	Contraction[a]	Expansion[a]	Cycle(T – T)[b]	Cycle(P – P)[b]
1945 (IV)–1975 (I)	10.57142857	52.4285714	63	62.57142857
1975 (II)–1991(I)	10	54	64	66.66666667
1991(I)–2011(I)[c]	11.33333333	69	80.33333333	80.66666667

$a - T - T$ Previous trough to this trough, $P - P$ Previous peak to this peak, $b - T - P$ in expansion, and $P - T$ in contraction, c-calculated by author based on U.S.GDP series

Kitchin Cycles, as witnessed. Particularly, since the 1970s, the wavelength of Juglar Cycles is elongating consistently.

In addition, by comparing the business cycle in 1947 (IV)–1976 (IV), 1977 (I)–1989 (IV) and 1990 (I)–2011 (IV), growth variances [here mainly referring to the GDP annual volatility] of the three sections are featured with decreasing trend (see Fig. 49.4), reflecting the overall economic fluctuation was gradually smoothening in postwar U.S. economy, which tallies with the findings of many scholars [8, 10, 12, 13].

Additionally, based on the data from U.S. NBER, U.S. postwar business cycle lengths prove slight elongations, particularly after 1990. This fact is consistent with the findings of this study (Table 49.3).

49.3 Conclusions

This paper explores empirically into post-war U.S. economic structural breakpoints identification. Based on our research, the U.S business cycles are evaluated, and we draw the following conclusions.

First, U.S. economic GDP series has two breakpoints in 1976 and 1989, and thus the postwar U.S. economy can be divided into three periods 1947–1976, 1977–1989 and 1989–2011.These findings are different from previous academic findings, to the effect that the U.S. economic structural breakpoint is at 1983–1984.

Second, the U.S. Juglar cycles have an elongating trend. Particularly, after 1990, the trend seems even significant. And U.S. Kitchin cycles have a lengthening trend as well, but the trend proves somewhat slight when compared with the former. Additionally, the amplitude of Juglar Cycle and Kitchin Cycles has witnessed a deceasing trend after WWII.

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Chapter 50
The Macroeconomic and Financial Effects of Oil Price Shocks

Song Zhou and Dong Wang

Abstract The oil price shock is considered as a major contributor to economic fluctuation. In this paper, we investigate whether the impulse responses of different macroeconomic variables and financial variables to the oil price shock and the effect of interest rates change. And we also use Granger Causality Test to evaluate the correlation between oil prices, stock markets and gold prices. Estimation results based on the U.S. data suggest that: (1) The oil price shock has a significant impact on inflation, stock markets and gold prices and it also has a short-term impact on interest rates. (2) Co-movement of oil prices, stock markets and gold prices exist. (3) Changing interest rates as monetary policy can induce price puzzle in order to reduce the inflation caused by the oil price shock.

Keywords VAR · Granger causality · Oil prices

50.1 Introduction

Since 1970s, the changes in the price of oil have been considered as an important indicator of economic fluctuation by many macroeconomists. And they are likely to affect financial markets and economies simultaneously. For example, crude oil spot prices, measured using West Texas Intermediate crude oil, still stayed at $20 per barrel in 2001 and the next 7 years had witnessed a steady increase to $124 per

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_50,

barrel, followed by a sharp decrease in 2009. Meanwhile, it is obvious that Dow Jones Index and gold prices experienced the similar movement from 2001 to 2009. Furthermore, the past study has explained the macroeconomic effects of oil shocks and the influence of oil price change on stock markets and gold prices. Kettering concludes that the increase in gold and oil prices would exert an adverse impact on the stock market movements [12]. And Darby [4] and Hamilton [10] were the first two economists to assess the impact of oil shock on U.S economy, who finds statistically correlation between the increase in crude oil price and real GNP growth for the U.S. economy (1948–1972 and 1973–1980). Hooker also argues that oil price effects on GDP of America changed qualitatively in 1980s [10]. As Blanchard and Gali points out, the effect of the increase in oil price has become mild in recent years [2].

Several economists [7, 13] also investigate whether the response of monetary authority behavior affects oil price changes. Tatom [14, 15] and Bernanke et al. [1] indicated that the rise in interest rates occurred prior to the economic downturn, which provided a possible explanation for recessions due to oil price shocks. However, Hamilton and Herrera subordinate the role of monetary policy in occurrence of contractions [6].

The purpose of this paper is to use vector autoregression (VAR) model to examine two hypotheses based on the current data: (1) Impact of crude oil price change can affect Real Gross Domestic Product (GDP), Consumer Price Index (CPI) and interest rates, (2) Co-movement of the oil price, stock markets and gold prices exist. (3) Interest rate change in U.S. can alleviate the negative influence from the oil price shock.

According to Hamilton, 'Vector autoregression(VAR) is a statistical model used to capture the linear interdependencies among multiple time series and VAR models generalize the univariate autoregression (AR) models [5]'. In this paper, we use VAR model to examine the impulse responses of other variables with respect to the price shock of crude oil and the interest rate change. And from impulse responses graph, correlation between oil price and macroeconomic effects can be illustrated. In addition, Granger Causality Tests will be used to examine the interaction between oil prices, stock index and gold prices. Consequently, VAR model and Granger Causality Tests are two approaches used in this article.

In this paper, the estimation results from VAR model based on U.S. quarterly data confirm that the oil price shock can lead to a series of changes among variables including inflation, interest rates, Dow Jones Index and the gold price. The increase in the oil price is expected to enhance the inflation instantaneously. Meanwhile, the oil price shock may affect stock market price negatively and contribute to an increase in the gold price. However, the effect on real GDP in U.S. is not significant. Furthermore, the VAR model also shows that the interest rate in U.S. is not expected to influence the oil price inversely on average. And the response of real GDP to enhancement in interest rates is prolonged negative. Lastly, according to Granger Causality Tests, the existence of co-movement of oil prices, the stock market prices and gold prices is significant.

The structure of the paper is as follows: Sect. 50.2 describes the VAR model used in the paper. Section 50.2.1 explains the selection of variables; Sect. 50.2.2 provides the VAR model background; and Sect. 50.2.3 justifies the identification strategy. Section 50.3 investigates the results of impulse responses and Granger Causality Test. In Sect. 50.4, concise summary and possible extension are presented.

The oil price shock can be considered as a herald of economic fluctuation. Hence, most manufactory companies need hedge against the financial risks based on the change of the oil price.

50.2 Methodology

50.2.1 Data

The variables used in the model include crude oil prices, the consumer price index (CPI), Real Gross Domestic Product (GDP), Dow Jones Average Index, interest rates (bank prime loan rate) and gold prices. Oil prices in the paper use quarterly average spot market prices on West Texas Intermediate crude oil, which is widely considered as a benchmark for world oil markets. Gold prices use mean value of quarterly gold Fixing Price in London Bullion Market based on U.S. Dollars (a benchmark for pricing the majority of gold products and derivatives throughout the world's markets). Dow Jones Industrial Average, also called the Industrial Average, is price-weighted average price of 30 stocks of publicly-owned companies, and is the second oldest and most-quoted U.S. market index after the Dow Jones Transportation Average.

We examine quarterly data for the period between 1973Q2 and 2012Q1. The first oil crisis erupted in October 1973, when the Organization of Arab Petroleum Exporting Countries (OAPEC) claimed an oil embargo. According to Hudson, on 15 August 1971, the United States had to terminate convertibility of the dollar to gold [11]. By February 1973, the price of gold had risen to $42.22 amazingly; by June 1973 the price of gold was $120 per ounce. Hence, 1973Q2 is selected as the start of the data in our model.

In addition, the data (oil prices, GDP, CPI, interest rates, Dow Jones Average Index and gold prices) are available from the Federal Reserve Bank of St. Louis. GDP, CPI and used in the VAR model are seasonally adjusted. For modeling purposes, all variables, with the exception of interest rates, are expressed in natural logarithms (log).

50.2.2 VAR Model

In this section, a VAR model is established in order to describe the macroeconomic effects including the influence on financial market brought by oil price shocks. The VAR model used in the paper is defined as follows:

$$Y_t = \sum_{i=1}^{2} A_{it} Y_{t-i} + u_t, \tag{50.1}$$

where Y_t is $p \times 1$ vector of observations on the dependent variables, u_t are independent $N(0, H_t)$ random vectors. And the error covariance H_t can be written as:

$$A_t H_t A_t' = \sum\nolimits_t \sum\nolimits_t{}', \tag{50.2}$$

where $\sum_t$ is a diagonal matrix and A_t is the lower triangular matrix.

Our VAR model is based on quarterly data for VAR model (50.1) is:

$$Y_t = \left[\log(oil), \log(GDP), \log(CPI), \log(r), \log(DowJones), \log(gold)\right].$$

50.2.3 Identification Strategy and Lag Length

$$\begin{bmatrix} u_{oil} \\ u_{gdp} \\ u_{cpi} \\ u_r \\ u_{djx} \\ u_{gold} \end{bmatrix} = \begin{bmatrix} t_{11} & 0 & 0 & 0 & 0 & 0 \\ t_{21} & t_{22} & 0 & 0 & 0 & 0 \\ t_{31} & t_{32} & t_{33} & 0 & 0 & 0 \\ t_{41} & t_{42} & t_{43} & t_{44} & 0 & 0 \\ t_{51} & t_{52} & t_{53} & t_{54} & t_{55} & 0 \\ t_{61} & t_{62} & t_{63} & t_{64} & t_{65} & t_{66} \end{bmatrix} = \begin{bmatrix} \varepsilon_{oil} \\ \varepsilon_{gdp} \\ \varepsilon_{cpi} \\ \varepsilon_r \\ \varepsilon_{djx} \\ \varepsilon_{gold} \end{bmatrix},$$

where subscript oil denotes $\log(oil)$, gdp denotes $\log(gdp)$, cpi denotes $\log(cpi)$, r denotes log(interest rates), djx denotes log(dow jones index), and $gold$ denotes $\log(gold)$.

In the system, oil prices do not react contemporaneously to shocks to other variables; GDP is not only affected by the oil price shock; inflation dose not respond contemporaneously to impulse from interest rates, Dow Jones Index and gold prices, but is affected by oil prices, GDP and inflation; interest rates as impulse can affect oil prices, GDP, CPI; Dow Jones Index is only not affected simultaneously by gold prices; and gold prices are influenced by all shocks.

As for the lag length, the number of lags is empirically determined to choose 2, because quarterly data is used in this VAR model.

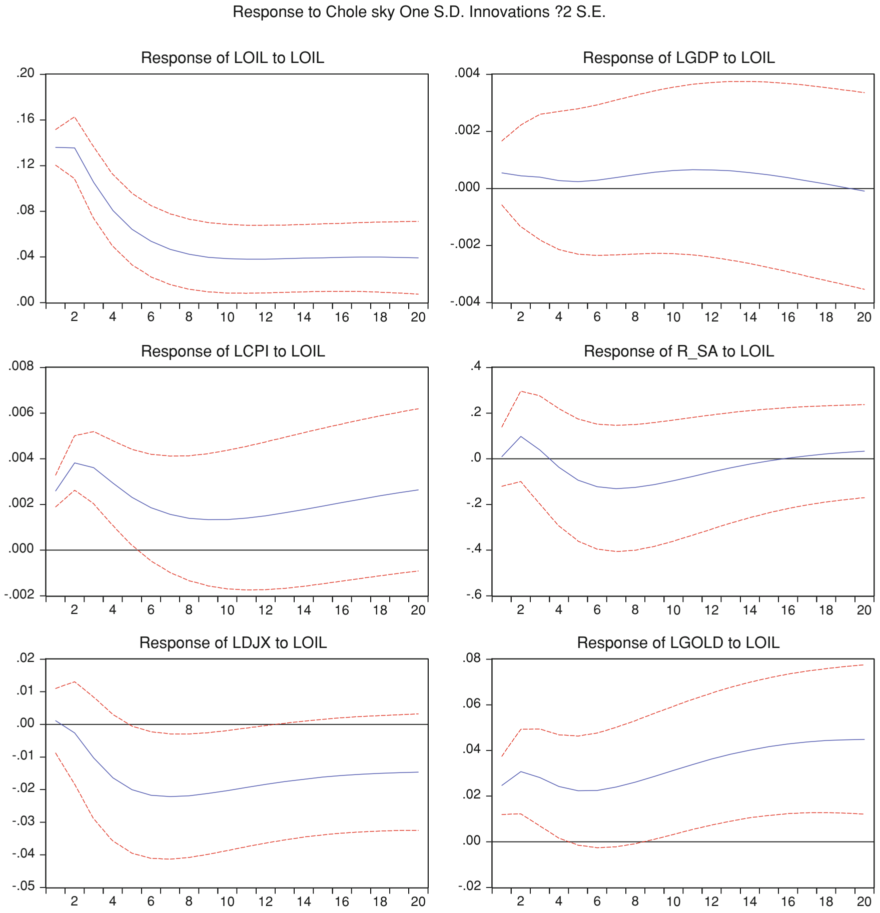

Fig. 50.1 US—Impulse response to an oil price shock from 1973Q2 to 2012Q1

50.3 Results

50.3.1 Impulse Response

Impulse response to an oil price and interest rate change shock from 1973Q2 to 2012Q1 are shown in Figs. 50.1 and 50.2 respectively.

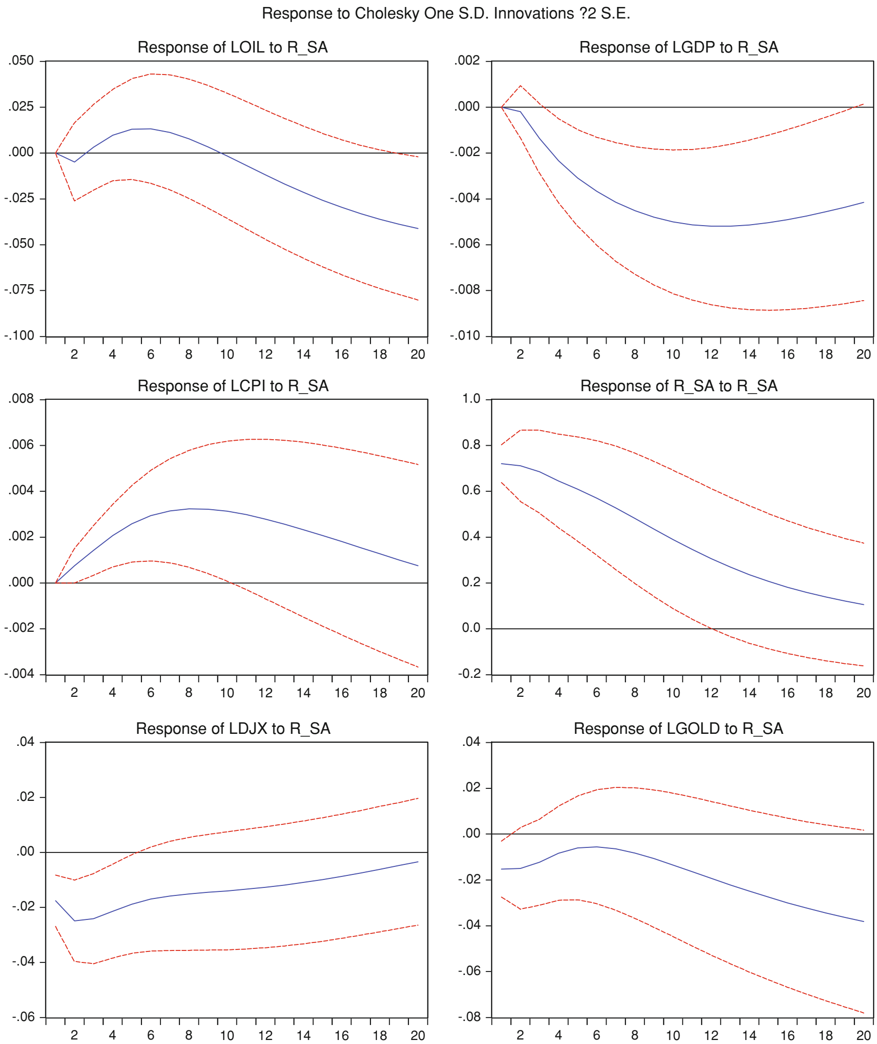

Fig. 50.2 US—Impulse response to an interest rate change from 1973Q2 to 2012Q1

50.3.2 Granger Causality Test

Furthermore, the response of Dow Jones Index was delayed and negative, whilst the movement of the gold prices was simultaneous with the crude oil price. According to Table 50.1, the statistical results from Granger Causality Tests indicate that the oil price, the gold price and the stock market index are influenced by each other, which implies the existence of causality between the stock price, the gold price and the oil price.

Table 50.1 Granger-causality test

Pairwise Granger causality tests

Date: 10/11/12 Time: 01:59 Sample: 1973Q2 2012Q1 Lags: 2

Null hypothesis:	Obs	F-statistic	Prob.
LOIL does not Granger cause LGOLD	154	1.52971	0.2200
LGOLD does not Granger cause LOIL	1.50333	0.2257	
LDJX does not Granger cause LGOLD	154	0.46890	0.6266
LGOLD does not Granger cause LDJX		0.52374	0.5934
LDJX does not Granger cause LOIL	154	1.54981	0.2157
LOIL does not Granger cause LDJX		0.51533	0.5984

50.3.3 Result Analysis

To analyze the intrinsic relationship between these variables, the critical role that oil plays in the economy is irreplaceable. Firstly, gasoline and diesel fuel are used as primary transportation fuels, which are derived from the crude oil. Therefore, the cost of production and transportation will rise along with the short-term increase in the oil price, which implies that the oil price shock may induce a worldwide surge in commodity prices and underlying inflation. In addition, facing the drastic growth in commodity prices, many people will choose to smooth consumption. The adverse factors including higher cost and lower profit hamper economic development and have a negative impact on the stock market. And low return in the stock market and potential high inflation are likely to encourage people to purchase gold as investment or speculation, which tends to trigger a sustained increase in the price of gold. Hamilton asserts an essential role for oil price increases as one of the main cause of recessions in U.S, since the increases in the price of oil haunt prior to the most recession [4, 5].

If the increase in oil prices seems to be prolonged, many firms may decide to invest in more energy-efficient capital and move from energy-intensive to energy-efficient firms, which is likely to induce an increase in unemployment during adjustment. And the adjustment costs often amplify the influence of oil prices shock and exert long-term negative effects on the economy. Additionally, facing prolonged increase in oil prices, people might try to substitute oil with alternative energy and this behavior response to the oil price shock is able to trigger an indirect inflation. According to Hojjat, one particularly salient example is that the rising price of petroleum in 2007–2008 not only increased the transportation costs of food, but also spurred the society to utilize biofuel as the alternative [8]; however, inadequate agricultural production could not cater to the rising demand of biofuel production and cereals for food consumption, thereby promoting the increase in the price of crops such as Maize.

However, all impulse response results correspond with the preceded expectation, except the real GDP. Cologni and Manera explains that 'a negative long-run effect of oil prices on excess output is not rejected by data [3]'. According to Hooker, one potential explanation (why oil prices change does not Granger cause macroeconomic variables in U.S.) is that the crude oil prices has been endogenous since 1973. So Hooker introduces 'net oil price increase' (NOPI) into VAR model to investigate the correlation between oil prices shock and U.S. Economy [9].

50.4 Conclusions

In this paper, we have examined the impulse responses of various economic indicators to oil price shocks. Based on U.S. data, the VAR model suggested that (1) on average, there is positive relationship among oil prices, inflation, interest rates and gold prices; the relationship between oil prices and stock prices is negative; the correlation between oil prices and real GDP is not significant. (2) Granger Causality tests confirms the existence of co-movement of oil prices, stock prices and gold prices. (3) Interest rates is ineffective in reducing the inflation due to oil price shock.

Possible future research efforts will follow Hooker [9], introducing 'net oil price increase' (NOPI), to assess the impact from oil price shocks on U.S. Economy. Secondly, potential asymmetry impact from oil price shocks need be taken into consideration. Furthermore, it is possible to introduce time-varying structural VAR method to investigate the effect of oil price shock in different periods.

Acknowledgments First of all, I would like to express my gratitude to my advisor, Prof. Fujiwara, who has given me constant help. Then I would like to thank my family members, who have been pouring out their encouragement to me.

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Chapter 51
The Multi-objective Optimization Model of the Industrial Structure in the Processes of Urbanization: A Case Study of Shizhong District, Neijiang City

Yunqiang Liu and Lu Gan

Abstract This article analyzes the structure of the three industries in Shizhong District, Neijiang city. Considering the economy, employment, resources, energy and environmental constraints with the achievement of the optimal economic and social benefits, a two-goal programming model is established. Based on the relevant data, this article uses fuzzy algorithm to solve the established planning model. The results of the model calculations demonstrate that industrial structure optimization is an effective way to achieve low-carbon development and also it provides a scientific basis for the industrial structure optimization in Shizhong District.

Keywords Industrial structure optimization · Multi-objective planning · Uncertain variable

51.1 Introduction

Detailed theories of industrial structure have been proposed for a couple of years. Marx [8] proposed the theory of industrial division, industrial structure equilibrium and adjustment mechanism of Industrial structure in nineteen century. It is the basement of analysis and adjustment of industrial structure. Fisher [5] put forward the three industry classification which classified the three industries firstly into primary, secondary and tertiary industries. Gonchijany [6] summarized the changing law of industrial structure and testified its importance to economic development.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_51,

Chenery [3] standardized the open industrial structure theory and put forward the development type theory. Besides, he got a group of standard data about the weight of vary manufacturing department related to the change of per capita income after calculation of fifty-one different countries. Lewis [7] proposed the binary structure transformation theory to explain the economic issues for developing countries. He thought that the whole economy is composed by the modern industrial department and traditional agriculture department and developing countries could make use of the advantage of labor resources to accelerate economic development.

Through maximizing (or minimizing) many different objective functions under a set of constraints, Multi-objective programming (MOP) is suitable for making decisions for the system involving two or more goals. MOP can deal with this situation and get solution. MOP has been greatly developed and used in many aspects. Zhao [12] used MOP to seek for Pareto optimal decision. Abdelaziz et al. [1] studied the portfolio selection by MOP. It's also been used in some other aspects [4, 9, 11]. Since Zimmermann [13, 14] first introduced conventional linear programming and multi-objective linear programming into fuzzy set theory, there is now an overwhelming amount of research on using fuzzy programming technique to solve multi-objective programming [2, 10].

51.2 Research Background

In the past 30 years, the region's GDP increased from 1.79 billion yuan in 1978 to 113.5 billion yuan in 2008, and the average annual growth rate is 11.5 %. In 2000, the region's GDP reached 30 billion and then the expansion of the total economy continues to accelerate. Since the Tenth Five-Year Plan, the average annual GDP growth rate has reached 12.9 %, which is 3.4 % points higher than the average annual growth rate since the reform and opening up. In particular, since 2002, the GDP maintains a double-digit growth for seven consecutive years. With an average annual growth rate of 12.8 %, the region's GDP per capita increased from 460 yuan in 1978 to 15,304 yuan in 2007. In 2008, the national economy continued to maintain a rapid growth in Shizhong District, and the quality of management achieved further improvement. Validated by the Municipal Bureau of Statistics, with an increase of 14.1 % over the previous year, the region's GDP in 2008 is 11,351,370,000 yuan, and the growth rate is 1.3 % points lower than last year. To be more specific, with an increase of 3.4 %, the added value of primary industry is 1.21845 billion yuan. With an increase of 17.1 %, the added value of the secondary industry is 5.40334 billion yuan. And with an increase of 13.0 %, the added value of tertiary industry is 4.72958 billion yuan. The contribution rates of the three industries in the economy are 2.2, 56.4 and 41.4 %, respectively, and the percentage points of stimulating economic growth are 0.3, 8.0 and 5.8, respectively. The added value of the three industries accounted for the proportion of GDP in the previous year is 11.0:45.5:43.5 and the proportion are adjusted to 10.7:47.6:41.7. As a result, The proportion of primary industry dropped by 0.3 % points, the secondary industry increased by 2.1 % points,

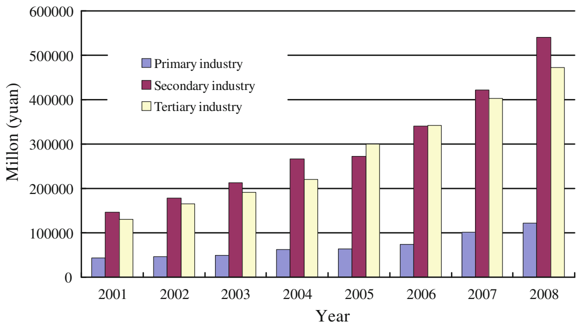

Fig. 51.1 The output value of three main industries

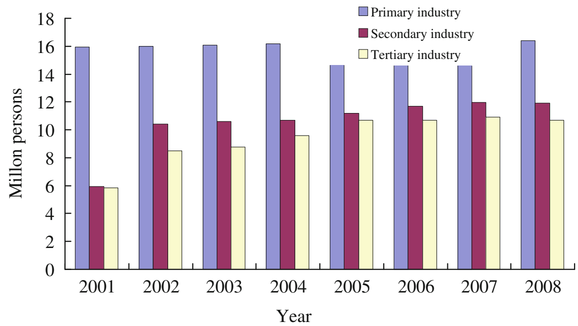

Fig. 51.2 The employment from 2002 to 2008

and the tertiary industry dropped by 1.8 % points. The total employments of the three industries are 16.4, 11.94 and 10.71 million respectively. Figures 51.1 and 51.2 show the output value and attracted employment in Shizhong District from 2002 to 2008.

According to the current exchange rate, the GDP per capita of Shizhong District is about $2,600 in 2008. Hence, it is appropriate to estimate the level of real income at a range of $2000–$3000. By comparing the industrial structure of Shizhong District with that of Chenery Standard in Table 51.1, it can be found that the proportion of secondary industry of Shizhong District in 2008 was significantly higher than that of geneary standard industrial structure and the proportion of tertiary industry was apparently lower than that of the standard industrial structure. The proportion of primary industry was slightly lower than the standard industrial structure. The productivity per capita in primary industry is low, and the GDP per capita is 7,430 yuan, only as weak as 1/5 of secondary industry and 1/6 of tertiary industry. According to the employment structure in 2008, the employment of primary industry was significantly higher than that of the standard industrial structure in Shizhong District; the employment of secondary industry was close to the standard industrial structure; the proportion of employment in tertiary industry was slightly lower than that of the standard industrial structure.

In this paper, a model which aims to solve industrial structure optimization problems is built by using multi-objective planning methodology. According to the development goals and reduction targets, the industrial structure optimization model under the constraints of environment and resource is established. By using the weighted fuzzy algorithm, a satisfactory solution is obtained. According to the decision-makers' different attentions on the two goals to assign different weights, adjustment and optimization program in different industries can be gained.

51.3 Modeling Techniques

The model of the industrial structure established in the low-carbon context should focus on economic efficiency as well as social interests. Economic development is the material security to promote social progress and enhance national strength. The realization of the social interest is the indispensable requirement of practicing people-oriented and building a harmonious society. At the same time, multiple targets are considered and expressed as multi-objective optimization in mathematics. This section will first introduce the multi-objective optimization theory, and then a model is built. Finally the data are input and by using the weighted fuzzy algorithm to get the optimized program.

1. Modeling Ideas

Taking economic construction as the center is a basic national policy determined at the beginning of reform and opening up. The rapid development of the economy is the right way to achieve the great rejuvenation of the nation. However, in China, a populous country, the blind development of technology-intensive and capital-intensive enterprises will inevitably lead to massive unemployment, thus causing social instability, which is contrary to build a harmonious society. Consequently, the building of industrial optimization model in Shizhong District should consider maximizing GDP and the employment as another target. The restraint system consists of the economic constraints, employment constraints, energy constraints and environmental constraints.

2. Modeling Process

In order to create a model and exclude secondary factors, some necessary assumptions of the problem should be made first. Then on the basis of these assumptions, a multi-objective programming model is established.
Modeling Assumptions

1. Assume that GDP growth in 2020 triples, then the average annual growth rate would be not less than 7 %. To avoid overheating of the economy, it is assumed that annual GDP growth rate does not exceed 20 %.
2. In 2008, the labor force absorbed by the three industries among which whose output values are over 10,000 yuan were 1.35, 0.22 and 0.23, respectively. Taking the rise in labor costs into account and based on the historical data that labor absorbed in the three industries whose output values are over ten thousand

yuan compared with that of last year, the ratio is 0.87:1, 0.92:1 and 0.91:1, we assume that such ratio will be uniformly maintained in a future period of time. Then $b_1(t) = 1.37 \times 0.87^t$, $b_2(t) = 0.22 \times 0.23^t$. Assuming that the new labor force was also 0.1 %, thus the net growth rate of the population 0.1 % in Shizhong District can be measured based on the historical data. In order to maintain the current unemployment rate, the annual number of new jobs can not be less than 0.1 % of the previous year.

3. Suppose that all energy consumptions are translated into standard coal, the conversion rate of carbon dioxide from standard coal is constant.
4. The base year energy consumption per unit of GDP is 1.23 tons of standard coal. The energy consumptions in the three industries are 0.36 tons of standard coal, 1.8 tons of standard coal and 0.72 tons of standard coal, respectively.
5. The adjustment period is one year.

Model Building

The basic framework of the model is shown as follows. The objective function:

1. The growth of the maximum output value of the total output reflects the growth of the economic benefits, that is to say, it can reflects the size of the economy. It is shown by the following objective function:

$$\max f_1(t) = x_1(t) + x_2(t) + x_3(t).$$

2. The growth of the employment reflects the growth of social welfare and the degree of social stability. It can be shown by the following objective function:

$$\max f_2(t) = 1.35 \times 0.87^t \times x_1(t) + 0.22 \times 0.91^t \times x_2(t) + 0.23 \times 0.92^t \times x_3(t).$$

Constraints:

1. Output value constraints: In order to achieve the overall objective of quadrupling the region's GDP in 2020, the annual economic growth rate 7 % can be calculated by assumption (1).

$$x_1(t) + x_2(t) + x_3(t) \geq 1135137 \times (1 + 7\,\%)^t.$$

2. Employment constraints: In order to control the unemployment rate, the annual increase in employment shall not be less than 1 % of the previous year.

$$1.35 \times x_1(t) \times 0.9^t + 0.22 \times x_2(t) \times 0.9^t + 0.23 \times x_3(t) \times 0.9^t \geq 580000 \times (1 + 0.1\,\%)^t.$$

3. Carbon emissions intensity constraints: In order to achieve the overall target of reducing the region's carbon emission intensity by 60 % lower than that of 2005 in 2020, the annual carbon emission intensity reduction target 6 % can be calculated. The carbon emission intensity constraint can be expressed as:

$$\frac{(0.36 \times p_1 \times x_1 + 1.8 \times p_2 \times x_2 + 0.72 \times p_3 \times x_3) \times 2.66}{x_1 + x_2 + x_3} \leq 0.68 \times 2.66 \times (1\text{–}6\,\%)^t,$$

which is equal to the following function:

$$0.36 \times p_1 \times x_1 + 1.8 \times p_2 \times x_2 + 0.72 \times p_3 \times x_3 \leq 1.23 \times (1\text{–}6\%)^t \times (x_1 + x_2 + x_3).$$

4. Sulfur dioxide emissions constraints: Considering the increased controlling efforts, an average annual increase of the sulfur dioxide processing rate 5 % is assumed. Due to the increase of the total economy, the absolute sulfur dioxide emissions may be also multiplying. The annual absolute increase is limited to not more than 5 % of last year, and then the following constraint is established:

$$2.8 \times (1 - 0.05)^t \times x_2 \leq 1494000 \times (1 + 0.05)^t.$$

5. Industrial wastewater discharge constraints: Considering the increased controlling efforts, an average annual increase of the wastewater treatment rate 5 % is assumed. Due to the increase of the total economy, the absolute sulfur dioxide emissions may be also multiplying. The annual absolute increase is limited to not more than 5 % of last year, then the following constraint is established:

$$28.9 \times (1 - 0.05)^t x_2 \leq 11127000 \times (1 + 0.05)^t.$$

6. Industrial soot emissions constraints: Considering the increased controlling efforts, an average annual increase of the soot handling rate 5 % is postulated. Due to the increase of the total economy, the absolute sulfur dioxide emissions may be also multiplying. The annual absolute increase is limited to not more than 5 % of last year, and then the following constraint can be established:

$$1.2 \times (1 - 0.05)^t x_2 630000 \times (1 + 0.05)^t.$$

7. Industrial dust emissions constraints: Considering the increased controlling efforts, an average annual increase of the dust processing rate 5 % is postulated. Due to the increase of the total economy, the absolute sulfur dioxide emissions may be also augmenting. The annual absolute increase is limited to not more than 5 % of last year, then the following constraint can be established:

$$0.281.2 \times (1 - 0.05)^t x_2 \leq 151000 \times (1 + 0.05)^t.$$

Solution to the Model

Let $t = 1$, then the following functions can be obtained: $f_1^0(1) = 1248651$, $f_1^1(1) = 1265678$, $f_2^0(1) = 390891$, $f_2^1(1) = 406406$.

Construct the membership function of the two goals

$$u_1(f_1(1)) = \frac{1265678 - (x_1(t) + x_2(t) + x_3(t))}{17027}, \tag{51.1}$$

$$u_2(f_2(1)) = \frac{406406 - (1.35x_1(t) + 0.22x_2(t) + 0.23x_3(t))}{15515}. \tag{51.2}$$

Table 51.1 Optimize results

Year	The proportion of primary industry	The proportion of secondary industry	The proportion of tertiary industry
2014	11.5	38.3	50.1
2015	11.5	38.4	50.0
2016	9.8	368.6	53.6
2017	9.5	35.5	55.0
2018	9.4	35.1	55.5
2019	9.3	33.7	57.0
2010	9.3	33.5	57.2

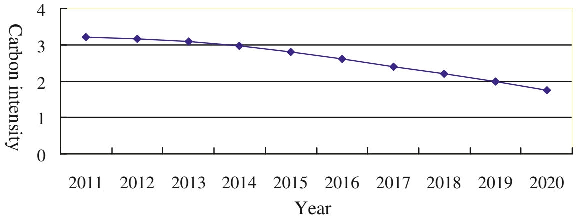

Fig. 51.3 Carbon intensity optimal value

If the decision-makers pay equal attention to the economic growth and employment promotion, then it can be assumed that weights of the two targets are 0.5 and the two membership functions are aggregated as $0.5u_1(f_1(1)) + 0.5u_2(f_2(1))$.

By using the Matlab Optimization Toolbox, the adjustment programs and results for 2014–2020 can be obtained (see Table 51.1).

When policy maker believes that the economic development is a very urgent task, he will confer more weight to GDP, such as 0.7. In turn, if policy maker believes that the economic development is not a very urgent task, he will confer less weight to GDP, such as 0.3.

51.4 Comprehensive Evaluation

Based on the above calculation results, it is not difficult to find that the overall trend is the same regardless of what kind of weights are assigned to the two targets by the decision-makers. That is, the primary industry remains stable and there is an obvious increase with the industrial efficiency. With the continuation of the industrialization process, the secondary industry's proportion of the national economy declines. The tertiary industry develops rapidly and replaced the secondary industry to become the leading industry in the national economy during the "Twelve Five-Year" Plan. By 2020, the proportion of the three industries is basically stable.

As for the aspect of energy conservation and carbon emissions intensity reduction, industries, in the existing technical conditions, should minimize the energy consumption per unit. At the same time, the optimization of industrial structure ought to shift to the low-emission industries. The superposition of twofold effect leads to an accelerated downward trend of the carbon emission intensity. By 2020, set $w_1 = w_2 = 0.5$ as an example, the carbon emission intensity will be 1.86 as shown in Fig. 51.3.

51.5 Policy Recommendations and Conclusion

Based on the calculation and analysis of the model, the following suggestions are proposed.

1. Consolidate the fundamental status of agriculture and improve agricultural efficiency. With the principle of "reduce, reuse, recycle", develop and utilize natural resources rationally, maintain essential ecological processes and life support systems in agricultural producing areas. Adhere to develop agriculture with the industrial concept, and around the central task of increasing income of farmers to adjust the industrial structure in rural areas. Focus on characteristic agriculture, and vigorously introduce and use eco-agricultural technology to innovate agricultural operation mechanism and speed up the construction of characteristic agricultural products in deep-processing enterprises. Strive to shift the traditional agriculture to the cycling ecological agriculture in Luzhou. And increase investment as well as strengthen infrastructure construction to promote the industrialization of agriculture, rural industrialization and rural urbanization. Furthermore, comprehensively improve the overall agricultural production capacity and agricultural efficiency and increase rural incomes to realize rural stability, and promote the cycling development of agricultural production and rural economic and social construction. Ultimately, establish a new socialist countryside which adheres to "integration of urban and rural areas, the development of production, affluent life, civilization, clean and tidy villages and democratic management".
2. Absorb advanced productive forces from science and technology and make good use of it. In accordance with the new requirements of the scientific concept of development and combined with the industry practice in Shizhong District, energetically develop low-carbon economy and circular economy, and finally do a good job in energy conservation. Such as photovoltaic in polysilicon industry, organic brand in tea industry and low-carbon economy in shoes industry. Use high-tech to grafting salt and phosphorus chemical industry, metallurgy and construction materials, machinery manufacturing and other traditional industries, and develop fine phosphorus chemical titanium, vanadium with low alloy steel, pure steel and other high-end new products. Furthermore, expand high-tech industries and develop silicon material, carbon fiber, rare earth, vanadium, titanium and other new materials to establish a cluster base for polycrystalline silicon photovoltaic energy industry. Finally, accelerate the strategic new industries, and

actively develop non-power civilian nuclear technology industry, the Internet of Things Radio Frequency technology industry and so on.

3. Develop the tertiary industry vigorously. Develop the tertiary industry energetically is the focus of the industrial adjustment. Tertiary industry bears the features of low energy consumption, less pollution and high efficiency. With the Buddha-Emei scenic tourist resources and a better transportation system and urban infrastructure in Shizhong District, it is potential to develop tourism, logistics and commerce. Tourism industry should be bigger and stronger. Increase the development of tourism resources integration and combine the tourism development with urban construction and the development of cultural industries with the beautiful mountains to further enhance the tourism grade. Improve the consumption environment and cultivate consumer hotspots, thus increasing the proportion of the services sector in the economy of the District.

Acknowledgments This research is supported by the Sichuan Center for Rural Development Research (Grant No. CR1320); the General Fund Project of Sichuan Provincial Department of Education (Grant No. 14ZB0014).

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Chapter 52
Multi Objective Production–Distribution Decision Making Model Under Fuzzy Random Environment

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Abstract Today the most important concern of the managers is to make their firms viable in the competitive trade world. Managers are looking effective tools for decision making in the complex business world. This paper addresses a hierarchical multi objective production-distribution planing problem under fuzzy random environment. A mathematical model is presented to describe the purpose problem. To deal the uncertain environment, the fuzzy random variables are first transformed into trapezoidal fuzzy numbers, and by using the expected value operation, the trapezoidal fuzzy numbers are subsequently defuzzified. For solving the multi-objective problem a weighted sum base genetic algorithm is applied. Finally, the result of a numerical example are presented to demonstrate the practical and efficiency of the optimized model.

Keywords Multi-objective optimization · Fuzzy lead-time · Fuzzy inventory cost parameters · Inventory planing · Interactive fuzzy decision making method

52.1 Introduction

A supply chain contains all activities that transform raw materials to final products and deliver them to the customers. Production-distribution (PD) planing is most important operational function in a supply chain. In today competitive environment, it is required to plan the products, manufactured and distribution, also need for higher efficiency, lower production cost and maximize the customer satisfaction. In general PD problems in supply chains, the decision maker attempts to achieve the following (a) set overall production levels for each product category for each source

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_52,

(manufacturers) to meet fluctuating or uncertain demand for various destinations (distributors) over the intermediate planning horizon, and (b) make right strategies regarding production, subcontracting, back-ordering, inventory and distribution levels, and thus determining appropriate resources to be used [1, 24]. Several methods and algorithms have been developed to solve various PD problems in certain environments [4, 5, 23].

In real-world PD problems, however, related environmental coefficients and parameters, including market demand, available labor levels and machine capacities, and cost/time coefficients, are often imprecise/fuzzy because of some information being incomplete or unobtainable. It is critical that the satisfying goal values should normally be uncertain as the cost coefficients and parameters are imprecise/fuzzy in practical PD problems [20, 24]. The practical PD problems generally have conflicting goals in term of the use of organizational resources, and these conflicting goals must be simultaneously optimized by the decision makers in the framework of imprecise aspiration levels [17, 18]. The conventional deterministic techniques cannot solve all integrating PD programming problems in uncertain environments. PD planning is a core issue influencing the producer, distributor and customer. The importance of PD planning has already been recognized [10, 23] and structure and different views of PD planning have been proposed in a great deal of research [2, 4, 15, 16, 21, 22].

The uncertainty in PD system is widely recognized because uncertainties exist in a variety of system components. As a result, the inherent complexity and stochastic uncertainty existing in real-world PD decision making have essentially placed them beyond conventional deterministic optimization methods. While, modeling a production distribution problem, production costs, purchasing, selling prices, transportation cost, delivery time and demand of products in the objectives and constraints are defined to be confirmed. However, it is seldom so in the real-life. For example, holding cost for an item is supposed to be dependent on the amount put in the storage. Similarly, set-up cost also depends upon the total quantity to be produced in a scheduling period, transportation cost depend upon the number of items delivered and scheduling the good network,delivery time also depend upon the production capacity and communication network. So, due to the specific requirements and local conditions, uncertainties may be associated with these variables and the above goals and parameters are normally vague and imprecise, i.e. fuzzy random variable in nature. However, from the previous study review, there appear to be few literature that deal with the uncertainty environment using both fuzziness and randomness in supply chain PD planning problem. Kwakernaak [13, 14] introduced a mathematical model by using fuzzy random variables, which was later developed more clearly by Kruse and Meyer [12]. In the Kwakernaak/Kruse and Meyer approaches, fuzzy random variables is viewed as a fuzzy perception/observation/report of a classical real-valued random variable. Xu and Pei [25] proposed a construction supply chain management PD planning, a bi-level model with demand and variable production costs with both fuzzy and random varieties is developed. From a probability space fuzzy random variable is a measurable function to a collection of fuzzy variables, so, roughly speaking, an fuzzy random variable is a random variable that takes fuzzy values. In this paper, for production-distribution planning, a bi-level multi objective model with demand, production costs, selling price and transportation costs all are considered as a fuzzy random.

This paper contributes to current research as follows: first, a multi-objectives model is proposed which considers two objective functions in large-scale industry which solve PD planing problem. In addition, fuzzy random variables are used to describe the demand,variable production costs, transportation cost and delivery time, which assists decision makers to make more effective and precise decisions. In the following sections of this paper is designed as follow. In Sect. 52.2 multi objective problem description and motivation of using fuzzy random variables are described. A mathematical model is used to optimized the production-distribution planing is explained in Sect. 52.3. In Sect. 52.4 fuzzy random simulation based genetic algorithm is explained. A numerical example is parented in Sect. 52.5 to show the significance of proposed model. At the end conclusions are given in Sect. 52.6.

52.2 Multi Objective Problem Description

This paper consider multi-objective PD problems examined here can be described as follows. Assume that the decision maker attempts to determine the integrating PD plan for K types of homogeneous commodities from L sources (factories) to M destinations (distribution centers) to satisfy the market demand. Every source has a supply of the commodity available to distribute to various destinations, and each destination has its forecast demand for the commodity to be received from the sources. The estimate demand, unit cost coefficients, and machine capacity are normally imprecise/fuzzy random owing to incomplete and unobtainable information over the intermediate planning horizon. This work focuses on developing a expected programming method for optimizing the PD plan in fuzzy random environments.

The need to describe uncertainty in PD planning is widely acknowledged because uncertainties exist in a variety of system components and a linkage to the regulated policies. In PD the source of the uncertainty mainly has four aspects in the PD planning: production cost; transportation cost, market demand and delivery time. Uncertainty in production mainly exist on the reliability of the production system. Such as; machine fault, change in input prices, executive deviation of the plan etc. Similarly, uncertainty exist in the market demand of the product. Randomness exist in the market demand because of change in product price and season, disaster, market competitors influence etc. Uncertainty also exist in transportation cost of product, transfer to the sale markets. Such as change in flue price, market distance from distribution center, quantity of order etc. Uncertainty may exist in the delivery time because of labor strike, machine working and shortage of components that help in manufacturing the products etc. Generally we define out the uncertainty first with the help of sampling analysis on the base of statistical data when considering the production cost, market demand, transportation cost and delivery time. Then we can value them and make fuzzy random variables with the help of expert experiences.

In such a case of study, because it is very difficult to estimate the accurate value of all these fuzzy random variables. It is mostly defined by giving a range in which the most possible value is considered as a random variable, i.e, viz (a, ρ, b). On the basis of statistics characteristics it is found that the most possible value of all these fuzzy random variables follow a normal distribution, i.e, $\rho \sim N(\mu, \sigma^2)$. To deal this situation the triangular fuzzy random variables (a, ρ, b), where $\rho \sim N(\mu, \sigma^2)$ is applied to deal with these uncertain parameters by combining fuzziness and randomness. As a consequence, it is appropriate to consider production cost, product demand, transportation cost and delivery time as a fuzzy random variables.

52.3 Modeling

In this section, a multi objective programming model for the PD planning considering fuzziness and randomness is constructed. The mathematical description of the problem is given as follows:

Index Sets
k: index for source, for all $i = 1, 2, \cdots, K$,
l: index for kind of product, for all $l = 1, 2, \cdots, L$,
j: index for destinations of delivery, for all $j = 1, 2, \cdots, J$.
Parameters
U_w: maximum inventory that can be store in warehouse,
$\tilde{\overline{C}}_{kl}$: Fuzzy random total cost of production per unit for product l by source i,
y_{kl}: inventory level of product k by source i,
h_{kl}: inventory holding cost per unit of product k by source i,
$\tilde{\overline{t}}_{kl}$: delivery cost per unit of product k by source i,
S_{kl} setup cost per unit of product k by source i,
$\tilde{\overline{P}}_{kl}$: production cost per unit of product k by source i,
r_{kl}: rate of production of product k by source i,
M_l: maximum level of production of source i,
p_t: delivery time period lengths,
$\tilde{\overline{T}}_{kl}$: per unit delivery time.
Decision Variables
X_{kl}: production volume of product k by source i,
p_t: delivery time periods length.

The multi objective optimization model of PD planing under fuzzy random environment is mathematically formulated as follow:
Objective function 1:
The first objective of PD plan is to minimize the total cost. The total cost of PD planing is composed by three parts namely total production cost which included regular production cost and setup cost, inventory holding cost and product delivery cost. The mathematical expression is as follow: min $F_1 = \sum_k \sum_l X_{kl}\tilde{\overline{C}}_{kl} + \sum_l \sum_k I_{kl} h_{kl} +$

$\sum_k \sum_l X_{kl}\tilde{\bar{t}}_{kl}$, where $\tilde{\bar{C}}_{kl} = \sum_k \sum_l S_{kl} + \sum_k \sum_l \tilde{\bar{P}}_{kl}$. There are some uncertain parameters in the objective function namely fuzzy random variables, $\tilde{\bar{C}}_{kl}$ and $\tilde{\bar{t}}_{kl}$, so it will be difficulty for decision makers to obtain the minimal cost accurately. Therefore, the decision makers usually only consider the average minimum cost by using the fuzzy random expected value model by Xu and Zhou as follow: min $F_1 = E\left[\sum_k \sum_l X_{kl}\tilde{\bar{C}}_{kl} + \sum_l \sum_k I_{kl}h_{kl} + \sum_k \sum_l X_{kl}\tilde{\bar{t}}_{kl}\right]$.

Constraint:

Sum of total available product is greater then sum of total demand of product: $\sum_k \sum_l X_{kl} \geq \tilde{\bar{D}}_{kl}$. There is uncertain parameter in the constraint namely fuzzy random variable $\tilde{\bar{D}}_{kl}$. Therefore, decision maker use fuzzy random expected value model to deal this as follow: $E\left[\sum_k \sum_l X_{kl} \geq \tilde{\bar{D}}_{kl}\right]$. The sources are working at maximum level: $\sum_k \sum_l r_{kl}X_{kl} \leq M_k$. Inventory level of product is less then the upper bound of warehouses: $0 \leq \sum_k \sum_l I_{kl} \leq U_w$.

Objective function 2:

The second objective of PD plan is to minimize the delivery time, which is mathematically formulated as follow: min $F_2 = \sum_k \sum_l X_{kl}\tilde{\bar{T}}_{kl}$. There is uncertain parameter in the constraint namely fuzzy random variable $\tilde{\bar{T}}_{kl}$. Therefore fuzzy random expected value model is used to minimize as follow: min $F_2 = E\left[\sum_k \sum_l X_{kl}\tilde{\bar{T}}_{kl}\right]$.

Constraint:

The total delivery time of product must be less than period time: $\sum_k \sum_l X_{kl}\tilde{\bar{T}}_{kl} \leq p_t$.

52.4 Solution Method

To solve the previous multi objective PD planing problem, four step are proposed. First, a fuzzy random variables transform into fuzzy trapezoidal numbers. Secondly, fuzzy simulation is applied to calculate the expected value of objective functions. Third, weighted sum method is used to transformed the multi objective into single objective. At the end a genetic algorithm is proposed to solve the above describe multi objective problem.

52.4.1 Dealing with Fuzzy Random Variables

Generally we know that, it is difficult to directly obtain an optimal solution of fuzzy random variables. Therefore, the fuzzy random variables convert into deterministic ones by the proposed transformation method. At First, the fuzzy random variables are transformed into fuzzy numbers, and then Heilpern [9] expected value operator is applied to to drive the deterministic variables.

Transformation of fuzzy numbers variables into fuzzy numbers

Total Production Cost. Generally, a fuzzy random variable is denoted as $\tilde{\tilde{\xi}} = ([m]_L, \rho(c), [m]_R)$. From the previous section, $\rho(\omega)$ is supposed to approximately follow a normal distribution $N(\mu_0, \sigma^2)$ with a probability density function of $\varphi_\rho(x)$, so the expression of $\varphi_\rho(x)$ should be $\varphi_\rho(x)$=$(1/\sqrt{2/pi\sigma_0}\exp[-(x-\mu_0)^2/2\sigma_0^2])$. Suppose that σ is a given probability level of random variable and $\sigma \in [0, \sup\varphi_\rho(x)]$, r is a given possibility level for the fuzzy variable and $r \in [r_l, 1]$, where $r_l = ([m]_R - [m]_L)/([m]_R - [m]_L + \rho_\sigma^R - \rho_\sigma^L)$, both of them reflecting the decision maker's degree of optimism. For an easy description, the probability level and the possibility level are called σ and r, respectively. The transformation method consists of the following steps:

1. Through historical data and professional experience using statistical laws, estimate the parameters $[m]_L,\ [m]_R,\ \mu_0$ and σ_0;
2. Obtain the decision maker's degree of optimism, i.e., the values of probability level $\sigma \in [0, sup\ \varphi_{\rho(x)}]$ and possibility level $r \in [r_l, 1]$, where $r_l = ([m]_R - [m]_L)/[m]_R - [m]_L + \rho_\sigma^R - \rho_\sigma^L)$, which are often determined by using a group-decision-making approach;
3. Let ρ_σ be the σ-cut of the random variable $\rho(c)$, that is $\rho_\sigma = [\rho_\sigma^L, \rho_\sigma^R = \{x \in R|\varphi_{\rho(x)} \geq \sigma\}]$, then, the value of ρ_σ^L and ρ_σ^R can be expressed as

$$\rho_\sigma^L = inf\{x \in R|\varphi_{\rho(x)} \geq \sigma\} = inf\varphi_\rho^{-1}(\sigma) = \mu_0 - \sqrt{-2\sigma_0^2 ln\sqrt{2\pi\sigma_0\sigma}}, \tag{52.1}$$

$$\rho_\sigma^R = sup\{x \in R|\varphi_{\rho(x)} \geq \sigma\} = sup\varphi_\rho^{-1}(\sigma) = \mu_0 - \sqrt{-2\sigma_0^2 ln\sqrt{2\pi\sigma_0\sigma}}. \tag{52.2}$$

4. Transform the fuzzy random variable $\tilde{\tilde{\xi}} = ([m]_L), \rho(c), [m]_R$ into the (r, σ) level trapezoidal fuzzy number $\tilde{c}_{\tilde{\tilde{\xi}}(r,\sigma)}$ by using the following equation:

$$\tilde{\tilde{\xi}} \rightarrow \tilde{c}_{\tilde{\tilde{\xi}}(r,\sigma)} = ([m]_L, \underline{m}, \overline{m}, [m]_R), \tag{52.3}$$

so

$$\underline{m} = [m]_R - r([m]_R - \rho_\sigma^L) = [m]_R - r([m]_R - \mu_0 + \sqrt{-2\sigma_0^2 ln\sqrt{2\pi\sigma_0\sigma}}), \tag{52.4}$$

$$\overline{m} = [m]_L + r(\rho_\sigma^R - [m]_L) = [m]_L + r(\mu_0 - [m]_L + \sqrt{-2\sigma_0^2 ln\sqrt{2\pi\sigma_0\sigma}}). \tag{52.5}$$

$\tilde{\tilde{\xi}}$ can be specified by $\tilde{c}_{\tilde{\tilde{\xi}}(r,\sigma)} = ([m]_L, \underline{m}, \overline{m}, [m]_R)$ with the following membership function:

$$\mu_{\tilde{c}_{\tilde{\tilde{\xi}}(r,\sigma)}} = \begin{cases} 0 & \text{for } x < [m]_L, x > [m]_R \\ \frac{x-[m]_L}{\underline{m}-[m]_L} & \text{for } [m]_L \leq x < \underline{m} \\ 1 & \text{for } \underline{m} \leq x \leq \overline{m} \\ \frac{[m]_R - x}{[m]_R - \overline{m}} & \text{for } \overline{m} < x \leq [m]_R. \end{cases} \tag{52.6}$$

The transformation process of fuzzy random variable $\tilde{\tilde{\xi}}$ to the (r, σ)-level trapezoidal fuzzy number $\tilde{c}_{\tilde{\tilde{\xi}}(r,\sigma)}$ is described in Eqs. (52.1)–(52.6).

Let $\tilde{\tilde{t}}_{kl}$ transportation cost, $\tilde{\tilde{D}}_{kl}$ demand of product and $\tilde{\tilde{T}}_{kl}$ per unit delivery time of product are also fuzzy random variables. Based on the previous method described for $\tilde{\tilde{c}}_{kl}$ total cost of production, can be transformed into (r, σ)-level trapezoidal fuzzy numbers.

52.4.2 Fuzzy Simulation for Expected Value

By using the fuzzy random simulation we can get the expected value of objective functions. The procedure is describe step by step as follow.

Step 1. Set $E[f(C, Q, \xi)] = 0$.
Step 2. Randomly generate $\mu_i,\ i = 1, 2, \cdots, m$ from the ε-level sets of ξ, where ε is a sufficiently small number.
Step 3. Set $a = f(C, Q, \mu_1) \wedge f(C, Q, \mu_2)\wedge, \cdots \wedge f(C, Q, \mu_m)$, $b = f(C, Q, \mu_1) \vee f(C, Q, \mu_2)\vee, \cdots \vee f(C, Q, \mu_m)$.
Step 4. Randomly generate r from $[a, b]$.
Step 5. If $r \geq 0$, then $E[f(C, Q, \xi)] \leftarrow E[f(C, Q, \xi)] + Cr[f(C, Q, \mu_1)] \geq r$.
Step 6. If $r < 0$, then $E[f(C, Q, \xi)] \leftarrow E[f(C, Q, \xi)] - Cr[f(C, Q, \mu_1)] \leq r$.
Step 7. Repeat the fourth to sixth steps for m times.
Step 8. $E[f(C, Q, \xi)] = a \vee 0 + b \wedge 0 + E[f(C, Q, \xi)].(b - a)/m$.

52.4.3 Weighted Sum Method

The weight sum method is one of the technique which is mostly applied to solve the multi-objective programming problem. By applying the weighted sum method we can convert the multi objective into single objective giving the weight of each objective function.

Assume that the related weight of the objective function $f_i(x)$ is w_i such that $\sum_{i=1}^{m} w_i = 1$ and $w_i \geq 0$. So we can construct the evaluation function as follows: $u(f(x)) = \sum_{i=1}^{m} w_i f_i(x) = w^t f(x)$, where w_i expresses the importance of the object $f_i(x)$ for decision maker. Then we get the following weight problem, $\min_{x \epsilon X} u(f(x)) = \min_{x \epsilon X} \sum_{i=1}^{m} w_i f_i(x) = \min_{x \epsilon X} w^t f(x)$.

52.4.4 Genetic Algorithm

In this subsection we have applied a stochastic search methods for optimization problems based on the mechanics of natural selection and natural genetics, genetic algorithms (GAs), which have received remarkable attention regarding their potential as a novel approach to multi objective optimization problems. GAs do not need many mathematical requirements and can handle any types of objective functions and constraints. GAs have been well discussed and summarized by several authors, e.g., Holland [11], Goldberg [8], Michalewicz [19], Fogel [6], Gen and Cheng [7] and Liu [3].

This section attempts to present a fuzzy random simulation and weighted sum method-based genetic algorithm to obtain a solution of multi objective programming with fuzzy random coefficients.

1. Representation structure: We use a vector $x = (x_1, x_2, \cdots, x_n)$ as a chromosome to represent a solution to the optimization problem.

2. Handling the constraints: To ensure the chromosomes generated by genetic operators are feasible, we can use the technique of fuzzy random simulation to check them.

3. Initializing process: Suppose that the DM is able to predetermine a region which contains the feasible set. Generate a random vector x from this region until a feasible one is accepted as a chromosome. Repeat the above process N_{pop_size} times, then we have N_{pop_size} initial feasible chromosomes $x^1, x^2, \cdots, x^{N_{pop\_size}}$.

4. Evaluation function: The regret value of each chromosome x is calculated, then the fitness function of each chromosome is computed by

$$eval(x) = \sum_{k=1}^{m} \frac{E[f_k(x, \xi)] - z_k^{\max}}{z_k^{\max} - z_k^{\min}}.$$

5. Selection process: The selection process is based on spinning the roulette wheel N_{pop_size} times. Each time a single chromosome for a new population is selected in the following way: Calculate the cumulative probability q_i for each chromosome x^i

$$q_0 = 0, \ q_i = \sum_{j=1}^{i} eval(x^j), \ i = 1, 2, \cdots, N_{pop\_size}.$$

Generate a random number r in $[0, q_{N_{pop\_size}}]$ and select the ith chromosome x^i such that $q_{i-1} < r \leq q\Gamma_i, \ 1 \leq i \leq N_{pop\_size}$. Repeat the above process N_{pop_size} times and we obtain N_{pop_size} copies of chromosomes.

6. Crossover operation: Generate a random number c from the open interval (0, 1) and the chromosome x^i is selected as a parent provided that $c < P_c$, where parameter P_c is the probability of crossover operation. Repeat this process N_{pop_size} times and $P_c.N_{pop\_size}$ chromosomes are expected to be selected to undergo the crossover operation. The crossover operator on x^1 and x^2 will produce two children y^1 and y^2 as follows: $y^1 = cx^1 + (1-c)x^2$, $y^2 = cx^2 + (1-c)x^1$.

If both children are feasible, then we replace the parents with them, or else we keep the feasible one if it exists. Repeat the above operation until two feasible children are obtained or a given number of cycles is finished.

7. Mutation operation: Similar to the crossover process, the chromosome x^i is selected as a parent to undergo the mutation operation provided that random number $m < P_m$, where parameter P_m as the probability of mutation operation. $P_m \cdot N_{pop\_size}$ chromosomes are expected to be selected after repeating the process N_{pop_size} times. Suppose that x^1 is chosen as a parent. Choose a mutation direction $d \epsilon R^n$ randomly. Replace x with $x + M \cdot d$ if $x + M \cdot d$ is feasible, otherwise we set M as a random number between 0 and M until it is feasible or a given number of cycles is finished. Here, M is a sufficiently large positive number.

We illustrate the fuzzy random simulation-based genetic algorithm procedure as follows:

Step 1. Input the parameters N_{pop_size}, P_c and P_m.
Step 2. Initialize N_{pop_size} chromosomes whose feasibility may be checked by fuzzy random simulation.
Step 3. Update the chromosomes by crossover and mutation operations and fuzzy random simulation is used to check the feasibility of offspring.
Step 4. Compute the fitness of each chromosome based on the regret value.
Step 5. Select the chromosomes by spinning the roulette wheel.
Step 6. Repeat the second to fourth steps for a given number of cycles.
Step 7. Report the best chromosome as the optimal solution.

52.5 Numerical Example

A numerical example is proposed in this section which illustrate the practical application of the proposed optimized model.

- Number of production plant (source): 1
- Numbers of distribution places: 4
- Fuzzy random cost of production: (140,$\rho(c)$, 160); where $\rho(c) \sim N(150, 4)$.
- Fuzzy random cost of transportation: $\tilde{\tilde{t}}_{11} = (4, \rho(t), 8)$; $\rho(t) \sim N(7, 1)$, $\tilde{\tilde{t}}_{12} = (3.5, \rho(t), 7)$; $\rho(t) \sim N(6, 0.8)$, $\tilde{\tilde{t}}_{13} = (4.2, \rho(t), 8.4)$; $\rho(t) \sim N(7, .9)$, $\tilde{\tilde{t}}_{14} = (4, \rho(t), 6.1)$; $\rho(t) \sim N(7, 1)$.
- Fuzzy random delivery time: $\tilde{\tilde{T}}_{11} = (8, \rho(T), 12)$;$\rho(T) \sim N(11, 1)$, $\tilde{\tilde{T}}_{12} = (6.5, \rho(T), 10)$; $\rho(T) \sim N(8, 0.8)$, $\tilde{\tilde{T}}_{13} = (8.5, \rho(T), 13)$; $\rho(T) \sim N(11, .95)$, $\tilde{\tilde{T}}_{14} = (6, \rho(T), 12)$; $\rho(T) \sim N(9.5, 1)$.
- Fuzzy random demand: $\tilde{\tilde{D}}_{11} = (80, \rho(D), 100)$; $\rho(D) \sim N(90, 4)$, $\tilde{\tilde{D}}_{12} = (60, \rho(D), 90)$; $\rho(D) \sim N(80, 3.5)$, $\tilde{\tilde{D}}_{13} = (85, \rho(D), 100)$; $\rho(D) \sim N(94, 4.1)$, $\tilde{\tilde{D}}_{14} = (65, \rho(D), 90)$; $\rho(D) \sim N(80, 3.5)$.
- Inventory Holding cost per unit: 2.

In the view of final solution of GA in Table 52.1, the producer can rationally allocate the production and save cost and delivery time. We have considered the

Table 52.1 The result of GA using weighted sum method

w_1	w_2	f_1^*	f_2^*	x_1^{1*}	x_2^{1*}	x_3^{1*}	x_4^{1*}	x_1^{2*}	x_2^{2*}	x_3^{2*}	x_4^{2*}
0.6	0.4	1,640	37	90	75	90	85	10	8	10	9

fuzziness and randomness at the same time when making planing which assist decision makers to make more accurate and well informed planing. Suppose the decision maker is not satisfied with the current solution when $w_1 = 0.6$ and $w_2 = 0.4$, so he can get the satisfied approximate solution by changing the weight coefficients of w_1 and w_2.

52.6 Conclusion

In this paper, we have proposed the multi objective production-distribution programming problem with fuzzy random coefficients. For a special type of fuzzy random variables, we have applied a method to transfer into fuzzy number and expected value operator was applied to get the deterministic variables. A fuzzy random simulation-based genetic algorithm using weighted sum method approach which is effective to solve the general fuzzy random multi objective programming problem. Though the fuzzy random simulation-based genetic algorithm proposed in this paper usually spends more CPU time than traditional algorithms, it is a viable and efficient way to deal with complex optimization problems involving randomness and fuzziness.In the future, fuzzy random simulation-based multi objective genetic algorithm is another field that we will consider.

Acknowledgments The authors wish to thank the anonymous referees for their helpful and constructive comments and suggestions. 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).

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Part IV
Supply Chain Management

Chapter 53
A Cross-Case Analysis of RFID Deployment in Fast Fashion Supply Chain

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Abstract The aim of this paper is to gain a better understanding on the deployment of the RFID in the fast fashion supply chain (FFSC), mainly its application in logistics operations, influence on performance, disadvantages, and barriers. The RFID experience of fifteen international FFSC companies is analysed. In the case studies the RFID in FFSC is deployed mainly to support receiving, tracking of raw materials, semi-finished components, and finished garments, and shipping logistics operations. The performance improvements recognized are: a decrease on stock outs, better production and supply availability, less shrinkage and theft, more efficient use of storage space, improvement in up selling, better inventory management, and process visibility. The RFID tag cost is the main disadvantage and the integration with current processes is the main barrier to the RFID deployment.

Keywords RFID · Fast fashion · Supply chain · Logistics operations · Case study

53.1 Introduction

The Radio Frequency Identification (RFID) technology can be expressed as a wireless identification method, which contributes to improve communication capabilities of electronic information associated to physical items [24]. It is composed by several elements including readers, tags, software, and security programs for the readers [3]. Its potential for inventory losses reduction, increase of efficiency, speed of processes,

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_53,

and improvement of information accuracy [29] makes RFID technology an important tool for organizations and supply chains (SCs) to sustain their competitive advantage [22]. The value of RFID technology is particularly visible in fashion supply chains (FSCs), as the fashion business is characterized by a wide assortment of products, short life-cycles, high seasonality, high volatility, high-impulse purchasing, and complicated distribution and logistics operations [11]. Peterson et al. [27] used the term "fast fashion" to describe a new business model where the tendencies are fresh new products, shorter life cycles, and faster production. In the highly competitive retail environment, the availability for a certain product category (or a specific item) is a relevant source of value to customers, since there are huge penalties due to stock outs of the current season "must-have" advertised items [9]. To respond to customer needs, time compression and flexibility should be developed in the entire supply chain (SC). Castelli and Brun [11] also stress the need to align operations of different members along the fast fashion supply chain (FFSC) by enhancing the information exchange through the use of new communication tools and process coordination practices. The objective of this research is to gain a better understanding of the RFID deployment in logistics operations, its influence on performance, and also the main disadvantages and barriers associated to the implementation of RFID. The analysis of the RFID application in a specific industry, considering a multinational scope, and collecting the perspective of companies positioned in different levels of the FFSC provides a deeper insight on the RFID deployment in this type of SC. The paper is organized as follows. After the introduction, RFID in a SC context and the application of the focused technology in FFSC logistics operations is present. Next, the theoretical framework is described, the methodology explained, case studies are presented, and the main conclusions are drawn.

53.2 RFID in the Supply Chain

Recently, there have been considerable investments in the development and improvement of RFID systems because of the important advantages that companies and SCs can reach in the management of their operations as compared to bar codes [12]. These advantages derive mainly from the innovation in the identification operations and also the elimination of the handmade work required to scan items. The RFID system also presents a high, rigorous, and simultaneous capacity of reading [31]; that could become an important source of competitive advantage and innovation in the logistics operations management field. This characteristic contributes to increasing the efficiency of a set of logistics operations such as those in material movements. For example, the efficiency in loading and unloading cargo is increased since warehouse operators do not have to manipulate an optical reader to collect data on the products being loaded or unloaded. Additional performance improvements are identified in Table 53.1.

As shown in Table 53.1, the application of RFID technology in a SC context can provide considerable performance improvements for all the SC members, namely,

Table 53.1 RFID performance improvements across the supply chain

Supply chain partners	Performance improvements in the literature
Manufacturers	• To decrease stock levels [21] • To decrease stock outs [32] • To increase production and supply availability [20] • Better quality during production • Quicker identification of products [7]
Distributors/ logistics providers	• To decrease stock outs [32] • To reduce shrinkage, theft, and more efficient use of storage space [18] • To reduce the number of incorrect manual counts, mislabeling, and inaccessible/misplaced inventory [21] • To minimize distribution errors [25] • To improve space use in warehouse and distribution center space [2] • To decrease charge back [32]
Retailers	• To improve up selling [3, 21] • To trigger an interactive display of related products [18] • To improve customer service [28] • To improve inventory management [31] • To reduce misplacement [25, 31] • To improve process visibility [31] • To reduce human errors [25] • Quicker collection of data [32] • To reduce shrinkage and theft [31]

in terms of operations optimization and efficiency. However, the RFID system implementation also brings some disadvantages. Kapoor et al. [19] identified technical issues (e.g., privacy and security violations, computer systems bottlenecks, and read errors) and economical issues (e.g., cost and obsolescence) that RFID implementations in supply chain management (SCM) must overcome. Beyond these disadvantages there are also some identified obstacles or barriers that would make difficult or contribute to the delay adopting this innovative technology. Figure 53.1 provides the main disadvantages and barriers of RFID deployment in the SC.

As shown in Fig. 53.1, the main disadvantages found in the literature on RFID deployments are related to the associated costs and its technological characteristics. Beyond this, the main barriers to a lack of widespread deployment of the RFID technology are associated to technological factors.

53.3 RFID in Logistics Operations of the Fast Fashion Supply Chain

The goals of SCM in the fashion and clothing industry are delivering the fashion trends at the right time in the right place, with increased variety, affordability, and customization; thus satisfying both the existing and potential customers needs [5]. The RFID deployment in FSC enables the access to real time item

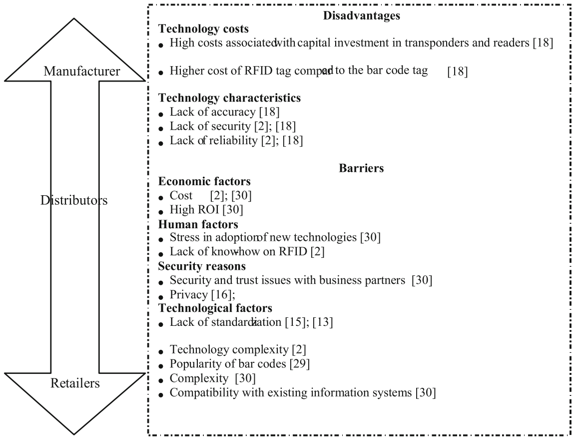

Fig. 53.1 Main RFID disadvantages and barriers in a supply chain context

information anywhere along the network supporting the SCM objectives in this challenging context. Hakim [15] also discusses the FSC characteristics that make it adequate for RFID utilization. First, the product variety is high and the different products are difficult to separate by a quick sight (e.g., different sizes of the clothes). Another issue in FSC management is the different needs of each SC member. From the manufacturer's point of view, since the product life cycle of fashion items is very short, it is vital to ensure product delivery to the stores as quickly as possible [8]. Gaukler and Seifert [13] discuss the usefulness of RFID in logistics operations across the SC, namely in reducing the bottlenecks, enabling a faster and less costly product movement, and improving inventory accuracy.In retailing, improvements in on-shelf availability of goods are expected by redesigning the shelf replenishment operations and creating transparency on the actual inventory in store, which improves inventory control [6]. Table 53.2 illustrates RFID deployment within different logistics operations across the SC members.

53.4 Methodology

The main objective of this research is to investigate the deployment of RFID technology in FFSC in order to identify the main logistics operations supported by it, the disadvantages, barriers, and performance improvements. A descriptive case study approach [34] is performed in this study. In this research data and investigator triangulations were used as explained below. The deployment of RFID in FFSC is explored from the point of view of RFID users (manufacturers/suppliers, distributors/logistics providers, and retailers in the FFSC). The secondary data for this research was gathered from the analysis of published literature based on a broad range of sources including newspapers, conference proceedings, industry reports, white papers, press releases, and books. In addition, specialized magazines on RFID, such as RFID

Table 53.2 RFID performance improvements across the supply chain

Supply chain partners	Logistics operations supported by RFID in FFSC	Authors
Manufacturer/supplier	• Packaging at production line end ()	Butcher [10] and Miragliotta et al. [23]
	• Receiving shipments	
	• Storage	
	• Inventory control and management	
	• Shipping	
	• Item tracking within manufacturing plant	
Distributor/logistics providers	• Packaging	Bottani et al. [8] and Miragliotta et al. [23]
	• Inventory control	
	• Shipping and item tracking	
	• Shipping consolidation loading	
	• Picking	
	• Receiving shipments	
	• Tracking of reusable packaging	
	• Verification	
	• Conveyance loading	
	• Conveyance tracking	
	• Order assembly	
Retailers	• Receiving shipments	Bottani et al. [8], Butcher [10], Miragliotta et al. [23] and Moon and Ngai [25]
	• Storage	
	• Inventory control	
	• Out-of-stock control	
	• Shop floor control	

Journal and Logistics Today, were used. The two criteria used to choose the RFID user companies for this research were: first the company must belong to a FFSC, and second the company must have deployed the RFID technology. Selected articles describing case studies were analyzed and, finally, selected aspects are briefly described with a special focus on logistics operations supported by RFID, performance improvements, disadvantages, and barriers of RFID technology deployment in FFSC.

53.5 Case Studies Findings

This section intends to illustrate the RFID deployment in FFSC. A case study approach is developed, considering fifteen companies from international FFSC. The companies experience with the RFID system is explored to identify: the logistics operations supported by the RFID, performance improvements, disadvantages, and barriers.

53.5.1 Space of the Case Study Profile

The representative case studies of the manufacturers companies are: the Basic House, Crystal Group, Griva, Lawsgroup, and Gerry Weber. The representatives of the logistics providers chosen include: the Jobstl Warehousing and Fashion, LTC-Logistics, and DHL Solutions Fashion companies. The fashion retailers that were chosen include: Charles Vogele Group, Kaufhof, Trottleman, American Apparel, s.Oliver Bernd Freier, and Benetton. The Iberlift Portugal was chosen as the representative RFID provider. The profiles of the research companies are presented based on their location, size, brands in the market, and facilities (Table 53.3).

As showed in Table 53.3, this study focused on companies in the FFSC that are based in different continents and countries including companies from Europe, Asia, and America. This makes a widespread comparison possible and enables a better understanding aboutthe RFID deployment in FFSC around the world. Also, all the companies have more than 150 employees and have adopted an international strategy with stores, plants, or warehouses in several countries.

53.5.2 RFID Deployment in FFSC Logistics Operations

In the world of fashion retail, the startup process of a collection assumes, more and more, a strategic role in what concerns the determination of invoicing. When the number of pieces begins to increase, it is critical that companies find new ways to make their processes more agile. Avoiding, not only, delays in receiving pieces in warehouses, but also the bottlenecks in the launching phase of a collection. This is possible with the SC members' synchronization through the RFID technology deployment. In the research case studies, several factors are highlighted as main enablers for the RFID deployment including the improvement of quality and logistics efficiency, information quality (Gerry Weber case), and the replacement of manual data-capture processes (Lawsgroup case). RFID technology has been deployed in different ways and contexts. With regard to the case studies in this research, RFID technology has been used in different kinds of logistics operations. As shown in Table 53.4, all the case studies deploy RFID to support several logistics operations, with "shipping" as the most common response. In addition, the tracking of products and reusable packaging are logistics operations where the RFID technology is commonly used. According to the experience of the RFID provider, RFID technology is used by most companies to support the tracking of raw materials, semi-finished components, and finished garments. This finding is quite similar to the results obtained from the RFID

Table 53.3 Case study profile

	Company	Based	No.[a]	Facilities
Manufacturers/suppliers	The basic house	Korean	271	30 outlet shops and have a plan to open 45 shops
	Crystal group	Hong Kong	35,000	15 manufacturing sites in Sri Lanka, Vietnam, China, Hong Kong, Macao, and Malaysia
	Griva	Italy	70	Main center covers a surface area of 5,000 m^2 plus a completely automated warehouse of 1,000 m^2
	VF corporation	USA	44,000	50 U.S. distribution centres and 1,000 owned/contracted factories
	Lawsgroup	Hong Kong	18,000	15 production sites, in Asia
	Gerry Weber	Germany	2,160	Several production facilities, 340 houses of Gerry Weber, over 1,480 shop and in-shop areas throughout the world and online shops
Distributor/logistics provider	Jöbstl warehousing and fashion	Austria	150	More than 60,000 m^2 warehouse space and a fleet of 40 trucks for distribution in Austria, Slovenia, the Czech Republic, the Slovak Republic, Croatia, Hungary and Romania
	LTC-Logistics	Italy	51–200	3 facilities located in Italy with a total of 24,000 m^2
	DHL solutions fashion	Germany	12,000	2.400 centers, storage area of 23,000,000 m^2, in more than 60 countries
Fashion retailers	Charles Vögele group	Switzerland	7,800	851 stores throughout Europe
	Kaufhof	Germany	19,000	145 stores
	Trottleman	Portugal	201–500	113 stores in Portugal and 3 in Spain
	American apparel	USA	10,000	260 stores in North America, Europe, and Asia
	s.Oliver Bernd Freier	Germany	6,500	49 own mega stores, 240 stores are run together with partners; is represented in 1.000 shops and on 1.330 sales stands
	Benetton	Italy		$\gg$5.000 stores globally

[a]No. of employees

Table 53.4 RFID deployment in FFSC logistics operations

Logistics operations supported by RFID		Case studies
Manufacturer/supplier	Packaging at production line end	(a), (b), (d)
	Shipping	(b), (c), (d)
	Item tracking within manufacturing plant	(b), (c), (e)
Distributor/logistics providers	Packaging	(h)
	Shipping and item tracking	(i), (h)
	Receiving shipments	(i), (h)
	Tracking of reusable packaging	(h)
Retailers	Receiving shipments	(p), (o), (l), (m)
	Inventory control	(0), (n)
	Shop floor control	(p), (l)

Legend (a) The basic house, (b) Crystal group, (c) Griva, (d) VF corporation, (e) Lawsgroup, (f) Gerry Weber, (g) Jöbstl warehousing and fashion, (h) LTC-logistics, (i) DHL solutions fashion, (j) Charles Vögele group, (l) Kaufhof, (m) Trottleman, (n) American apparel, (o) s.Oliver Bernd Freier, (p) Benetton

users companies. According to Further manufacturers and suppliers RFID is mainly used to support the packaging, shipping, and item tracking as illustrated in Table 53.4.

This result is in line with Bottani et al. [8], whose research defends the deployment of RFID by FFSC manufacturers in tracking and tracing items as a way of shortening production and delivery cycles. Beyond these logistics operations identified in the literature, some of the research companies deployed RFID in different areas such as receiving operations (Crystal group), handling (Gerry Weber), and collecting finish goods (Lawsgroup). Most of the distributors/logistics providers deployed RFID to support logistics operations related to shipping. Among the distributors/logistics research companies, RFID is also used to support logistics operations not previously identified in the literature, for example in receiving operations (DHL and LTC-Logistics) and in handling processes (DHL and LTC-Logistics). It is also interesting to note that there is one distributor/logistics provider (Jöbstl Warehousing and Fashion) that has not deployed RFID to support any of the logistics operations discussed in this study. This company uses RFID to track the movement of clothing items to stores and also to manage containers in its own distribution centre. With regard retailers, most of them deployed RFID in supporting logistics operations related to shipments. Also, retailers identified operations associated to inventory management and to shop floor control as being supported by RFID. In summary, according to the analysis of the fifteen companies it is possible to infer that companies in the FFSC deploy RFID in logistics operations.

53.5.3 The RFID Impact on FFSC Performance Improvements

With regards the influence of RFID technology on FFSC performance improvements, the manufacturers/suppliers companies highlight the decrease of stock outs and

Table 53.5 Performance improvements with the RFID technology deployment in FFSC

Performance improvements with the RFID		Case studies
Manufacturer/ supplier	To decrease stock levels	(e)
	To decrease stock outs	(a), (d), (e), (f)
	Production and supply availability	(a), (b), (e)
	Better quality during production	(f)
	Quicker identification of products	(c), (e)
Distributors/logistics	To reduce shrinkage and theft, and more efficient use of storage space	(h), (g)
Providers	To reduce the number of incorrect manual counts, mislabeling, and inaccessible/misplaced inventory	(i)
	To minimize distribution errors	(g)
	To improve space use in warehouse and distribution center space	(g)
	To decrease charge back	(h), (i), (g)
Retailers	To improve up selling	(p), (o), (m), (n)
	To trigger an interactive display of related products	(l), (m)
	To improve customer service	(l)
	To improve inventory management	(p), (o), (j), (l), (m)
	To reduce misplacement	(j)
	To improve process visibility	(j), (m)
	To reduce human errors	(l)
	Quicker collection of data	(l)
	To reduce shrinkage and theft	(l), (n)

Legend the same as Table 53.4

production and supply availability as main performance improvements associated to the RFID deployment as shown in Table 53.5. These two performance improvements are also recognized as the most important factors by the RFID provider. Only two companies identify the "quicker identification of products" and one company the "decrease on stock levels" and "better quality during production". Beyond the proposed improvements in performance focused on this study, some manufacturing companies identify others such as lead-time reduction, cost savings, workflow improvements, and efficiency improvement.

In analyzing the perspective of distributors/logistics providers on the performance improvements associated with RFID, all three companies highlighted the decrease in charge back. The next benefit identified by two companies was reducing shrinkage and theft, and more efficient use of storage space. Considering the point of view of retailers, most recognized the RFID contribution to improve inventory management. Three retailers selected the improvement associated with the improvement of the up selling and only two selected the following: (1) trigger an interactive display of related; (2) improve process visibility; and (3) reduce shrinkage and theft.

Although a high cost of investment is required and ROI is a concern, it is possible to attain a considerable cost savings by deploying RFID technology. The Jöbstl

Warehousing and Fashion realized a twenty percent cost savings stemming from increased container utilization after the RFID deployment [33]. Lead-time reduction was identified as a benefit by companies in different FFSC positions, manufacturers, logistics providers, and fashion retailers.

The Throttleman company case study clearly illustrated the lead-time reduction. The Portuguese fashion retailer has reduced the time items spend in the SC from 7 to 5 days. Quick identification of items as they arrive from the manufacturer in India ensures that the right items are shipped to its stores in Portugal and Spain rapidly. After the implementation of this solution, the performance of the receiving lead-time was improved. Before implementation, the average of receiving lead-time was 4.97 days and after RFID deployment it was reduced to less than 24 h [4]. Also, increased visibility was attributed to the RFID deployment by logistics providers, specifically the one associated to the inventory control (Table 53.2). The evidence from Table 53.5 indicates that the most referred performance improvement of RFID deployment in the FFSC isrelated to inventory measures (e.g., decrease stock outs, improve inventory management).

53.5.4 RFID Disadvantages and Barriers in FFSCM

Beyond the set of performance improvements associated with RFID technology, some disadvantages and barriers were derived from the case studies (Fig. 53.2). The main disadvantage attributed by FFSC companies with RFID technology is its cost: (1) the unit cost of tags, and (2) the costs associated tothe infrastructure and software system. In the Throttleman case, the investment in the entire project RFID was relatively low; however the largest cost was attributed to the tags, since it costs four times more than the traditional bar codes [1]. The cost associated to the system is also highlighted as a disadvantage by the fashion manufacturers Gerry Weber, the logistics provider, the Jöbstl Warehousing and Fashion, and the retailers. Oliver Bernd Freier and the American Apparel. Moreover, The tags' cost is recognized as an important disadvantage by the manufacturers VF Corporation and Gerry Weber, the logistics provider, the Jöbstl Warehousing and Fashion, and the retailers Kaufhof and Trottleman.

These disadvantages associated to the RFID technology are responsible for companies not using it, but there are also some barriers that make its widespread use more difficult.Among the barriers identified in Fig. 53.2, the integration with current processes and customer privacy are the most recognized by RFID users companies. In almost all cases, the introduction of this technology requires process reengineering in an attempt to reach the maximum potential and efficiency of the technology. Sometimes this is not viewed in a positive wayby companies and by employees in particular.

		Manufacturers/ Suppliers						***Distributors /Logistics provider***			***Retailers***					
		Cristal group	Basic house	Griva	VF Corporation	Lawsgroup	Gerry Weber	DHL	LTC	Jöbstl Warehousing	Benetton	s.Oliver Bernd Freier	Charles Vögele Group	Kaufhof	Throttleman	American Apparel
Disadvantages	Tag cost				X		X			X				X	X	
	System cost						X			X		X				X
	Insufficient read rates						X		X							
	RFID system was not scaling cost-effectively															X
Barriers	Customer privacy				X		X	X		X				X		X
	Integration with current process				X			X	X		X					
	Supply chain cost/benefit sharing			X			X			X						
	Bar code system				X			X								
	Global standardization				X									X		
	Change management					X							X			
	Alignment of its business processes													X		
	ROI estimation					X										
	Technology				X											
	Cultural issues				X											

Fig. 53.2 Disadvantages and barriers of the RFID technology

53.6 Conclusions

RFID is an innovative technology that has reached many applications due to the large potential that it presents for companies individually or as part of integrated SC. The fashion industry has unique requirements since retailers are locked in a battle to get key fashion trends from the design table to the shelves as quickly as possible. In this context, RFID technology offers performance improvements to respond to this challenge.

The main performance improvements associated to the RFID deployment highlighted by the case studies companies in order of importance are: internal inventory control, lead-time reduction, and cost savings. These performance improvements reached by the RFID deployment are strategic for the FFSC since this industry to become more competitive needs to shorten the time to market and delivery lead-time of the fashion trends, offering a great variety of products [5, 8]. These performance improvements are also related to the impact on logistics operations, mainly to the following: (1) packaging at production line end, shipping, and item tracking within manufacturing plant in the case of manufacturers/suppliers; (2) shipping and item tracking, receiving shipments to the distributors/logistics providers; and (3) receiving shipments, inventory control and shop floor control to the retailers. Apart from the special characteristics of FFSC, this SC has to deal also with the global sourcing. This means that many of the FFSC partners could be sited in other country or continent offering not only lower costs but also contributing to longer lead times. These create very pressing situations on companies and SC' managers, which have to make strategic decisions such as investing in RFID technology to support the logistics operations identified in this study to help shorten the lead times and become the FFSC more agile.

Despite the important contribution of this paper, there are limitations of the study that should be noted. The conceptual model was developed using anecdotal and empirical evidence present in the literature and no validation was performed. It is necessary to conduct further research concerning the RFID deployment in FFSC. Future research should collect large samples of empirical data on the FFSC to analyze RFID deployment in this type of SC.

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Chapter 54
Capacity Allocation Model of Air Cargo with the Differences in Transport Time

Li Luo, Yong Lei and Jing Yuan

Abstract Capacity allocation is the coreaut]Li Luo of air cargo revenue management. Nearly all the existingaut]Jing Yuan studies are conducted under the assumptionaut]Yong Lei of the equal transport time, overlooking the differences in transport time for the cargo in the actual operating processes. In fact, according to the foregoing differences, air cargo can be divided into urgent and general cargo. Urgent cargo should be transport as soon as possible, while the general one can be delayed within a certain time limit. In the light of the actual cargo loading demand, this paper proposes a dynamic programming model for air cargo capacity allocation so as to get the maximum revenue of a single-leg flight. Then simulation validates the effectiveness of the strategy suggested in this paper.

Keywords Air cargo · Revenue management · Capacity allocation · Transport time

54.1 Introduction

In recent years, with the rapid development of international economic and trade, the air cargo industry with its unparalleled advantages maintains a tremendous growth, which has become a new profit growth point for the air transport enterprises. Some well-known airlines such as Lufthansa, KLM Royal Dutch Airlines, have implemented the methods of cargo revenue management by phases and obtained a freight revenue growth of 2–5 %. However, the development of air cargo in China is later than the developed countries, the methods for better management and scientific

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_54, © Springer-Verlag Berlin Heidelberg 2014

decision have not been found for the revenue management strategies including capacity optimization, inventory control and pricing. Therefore, some problems have been raised in front of unprecedented development for air cargo. And some of them are determined by the industry particularities. Currently, air cargo is conducted mainly depend on cargo planes and passenger planes, and the transportation by passenger planes has accounted for a great majority of the air cargo business. The retentions of customers' goods are frequently happened due to the limited capacity of the planes, the obvious uncertainty and variability of the market demands as well as the lack of scientific management methods. This inability of on time transportation not only brings negative influence to the customer relationship but also makes the expensive capacity resources wasted. Owing to the diversity and the different transportation requirements of the goods along with considerable uncertainties in the weight and volume of them, the scientific inventory control for the space has become one of the important issues in the decision-making process for the air cargo industry.

54.2 Literature Review

The air cargo revenue management can be defined as selling the right cargo products (cargo space and cargo services) to the right customers at the right time for the right price. Due to the perishability of the space in the cargo planes and passenger planes, the strategies of air cargo revenue management can be divided into dynamic pricing, inventory control and overbooking. But the cargo space has multidimensional natures such as weight, volume, shape and size and its capacity is easily affected by the weather, the weight of fuel and passenger baggage, so air cargo revenue management cannot be simply substituted by passenger revenue management.

The research on air cargo revenue management starts from the late 1900s. Kasilingam [5] detailedly analyzes the difference between air cargo revenue management and passenger revenue management for the first time. The author gives the four steps for the analysis of air cargo revenue management, proposes the implementation model, and points out that the strategies for space control is one of the research areas with great potential in the future. The representative research on air cargo revenue management after Kasilingam [5] are as follows: Kasilingam [6] supposes that the capacity, distribution of occurrence rate, overbooking cost and idle cost are given, and develops a simplified one-dimensional model. By minimizing of the sum of the two costs, the author finally obtains the optimal overbooking level. Luo et al. [8] extend the one-dimensional model of Kasilingam to a two-dimensional model for air cargo overbooking. They believe that both the size and weight of the goods can be overbooked. By applying the methods of rectangular approximation and marginal analysis, the authors give out the mathematical model with the objective of minimizing the cost, and obtain the approximate overbooking level. The effectiveness of their model is also verified in practice. On the basis of Luo et al., Moussawi and Cakanyildirim [9] create an overbooking model in order to maximize the revenue, and calculate the approximate optimal level of overbooking. From the viewpoint of the agents, Chew et al. [2] determine the short-term space booking strategies with the lowest transportation costs by establishing of the stochastic dynamic programming model. The model considers the delayed transportation of the goods. But the assumption is only limited to one dimension. And it does not take the revenue of the air cargo companies into account. Rivi Sandhu [11] tries to solve the network transportation problems. The author develops the inventory control model for static planning which considers the revenues both from the passengers and the goods. In this model, the volumes of the goods are simplified to containers with fixed sizes. The author approximately calculates the maximum expected total revenue of the flights across the whole network by the method of Bender dimension reduction. Amaruchkul et al. [1] establish the Markov decision model to discuss the inventory control model for single-leg air cargo revenue management while the volumes of goods are stochastic and multidimensional. When study on the strategies for inventory control in air cargo revenue management, Andreea Popescu et al. [10] divide the goods into small goods (mail, parcels) and bulk goods. They use the linear programming model and dynamic programming model to solve the problem for those two types of goods respectively. The simulation shows that the results of the proposed method are superior to the traditional first-come first transported and static planning methods. Levin and Nediak [7] divide the agents into contract clients and protocol clients. They build a dynamic programming model for inventory and verify the validity of it by a numeral example. Wang and Kao [13] decide the capacity for air cargo overbooking by fuzzy systems with the consideration of the uncertainty environment Huang and Chang [4] consider the randomness of the goods' volume and weight. They present the algorithm to solve the problems of air cargo revenue management based on the estimates of expected revenue function for the dynamic pricing model. Han et al. [3] think about the capacity allocation problems for the single-leg air cargo revenue management. They assume that the volume, weight and yield of the goods are all stochastic, and the booking process has the Markov property. The decision of whether accept the booking requests or not follows the bid control model. Particularly, as to one piece of goods, it will not be accepted unless its revenue is greater than the opportunity cost. The optimal decision is determined by the maximizing the reward function in the Markov chain.

To sum up, except Chew et al. [2], the current research on air cargo revenue management all under the assumption of first come first transported and the permit of goods delay, overlooking the differences in transport time for the cargo in the actual operating processes. In fact, air cargo can be divided into urgent and general cargo. Urgent cargo should be transport as soon as possible, while the general one can be delayed within a certain time limit. Consequently, associated with the actual operation for the loading of the air cargo, this paper develops a dynamic programming model with the consideration of the differences in transport time for the cargo and the two-dimensional characteristics of the space. The proposed model can provide the inventory control strategies for the single-leg air cargo revenue management. The objective of this paper is to better serve the practice of air cargo revenue management.

54.3 Modeling

1. Problem Statement

Usually the air cargo companies start to receive cargo booking from the day before the scheduled departure time of the flight (that is to say, 48 h in advance). During the peak seasons, the supply of the flight is often unable to meet the demand. Faced with this situation, the traditional practices of the control center is to receive and transport the cargo in accordance with the arrival sequence of it. When the capacity is not enough, the cargo which arrives late will be refused. Throughout the booking process, the arrival of the cargo can be generally divided into two types: urgent cargo and general cargo. The urgent cargo has a higher transportation price and a stricter timeliness requirement for transportation. Delay is usually disallowed for the urgent cargo. On the contrary, general cargo has a lower transportation price and a less strict timeliness requirement for transportation. Usually, an appropriate delay is allowed if the cargo can arrive at the destination within a certain period of time. Although the traditional strategy perfectly ensure that all the received cargo can be transported and the customer satisfaction is maintained at a high level, it ignores the differences in the transportation between the urgent and general cargo: on the one hand, it provides the urgent service to the general cargo with a lower transportation price, which increases an unnecessary cost of service; on the other hand, the later arrived cargo with a higher transportation price will be refused because the received general cargo has occupied the space, which results in the loss of potential benefits. Therefore, in this paper, we mainly focus on minimizing the loss of potential benefits of air cargo, without reducing the quality of service and affecting the perception of customer service. The objective of this study is to maximize the total revenue of a single flight and minimize the punishment cost of delay transportation by reasonable acceptance and transportation of cargo when the loading capacity is constant.

2. Modeling

Consider the peak season for transportation (that is to say, the demand is greater than supply), the maximum loading weight and volume of flight A are k_w and k_v respectively. The booking time t is discrete and $0 \leq t \leq T$. $t = 0$ indicates the start of booking. $t = T$ expresses the end of booking which means the plane takes off with full cargo. Describe the problem using dynamic programming: split the intervals into small ones and assume that at each stage t, at most one booking requirement will arrive. Suppose there are two types of the booking requirements: $i = 1, 2,\ i = 1$ indicates the urgent cargo and $i = 2$ indicates the general cargo. The unit price and penalty cost of requirement i are h_i and r_i respectively. Usually, the urgent cargo cannot be delayed while the appropriate delay for the general cargo is allowed, so $h_1 \to +\infty,\ h_2 = r_2$. The transportation delay of the received urgent cargo will bring significant loss to the reputation of the air company, so $h_1 \to +\infty$. The transportation delay of the general cargo is equivalent to the return of the received order. And the order will be received again in the nest flight as compensation. So for the current flight, the revenue of receiving orders turns to be 0, $h_2 = r_2$. In the booking period, the weight w_i and volume v_i of the requirement i are the random variables which respectively follow the distribution of ϕ_i and ψ_i, and the expected income for requirement i is $r_i w_i$. p_{it} states the arrival probability of requirement i during the time period t, and $p_{0t} = 1 - \sum_{i=1,2} p_{it}$ expresses the probability of zero booking requirement during the time period t.

When $t < T$, the value function $U_t(x_w, x_v)$ represents the maximum expected revenue from time t to the end of booking when the remaining available weight is x_w and the remaining volume is x_v. Then the Bellman equation of $U_t(x_w, x_v)$ is:

$$U_t(x_w, x_v) = \sum_{i=1,2} p_{it} \max\{U_{t+1}(x_w - w_{it}, x_v - v_{it}) + r_i w_{it}, U_{t+1}(x_w, x_v)\} + p_{0t} U_{t+1}(x_w, x_v). \tag{54.1}$$

In this equation, w_{it} and v_{it} indicate the weight and volume of the cargo during arriving period t. And they are also the random variables which respectively follow the distribution of ϕ_i and ψ_i. The economic significance of Eq. (54.1) can be explained as follows: the maximum expected revenue from time t to the end of booking when the remaining available weight is x_w and the remaining volume is x_v should be equal to the sum of the maximum expected revenue when the cargo may arrive at time t and the maximum expected revenue when the cargo may not arrive at time t.

When $t = T$ and after the end of the booking, w_{ij_i} and v_{ij_i} $(j_i = 1, 2, \cdots, J_i)$ indicate weight and size of the j_ith cargo of type i which has been accepted. J_i is the total amount of the received cargo of type i. $C(J_i)$ is the penalty cost of transportation by plane. Then the optimization problem of cargo loading can be expressed by the following programming model:

$$\min C(J_i) = \sum_{i=1,2} \sum_{j_i=1}^{J_i} h_i w_{ij_i}(1 - a_{ij_i}), \tag{54.2}$$

Subject to

$$\sum_{i=1,2} \sum_{j_i=1}^{J_i} w_{ij_i} a_{ij_i} \le k_w, \tag{54.3}$$

$$\sum_{i=1,2} \sum_{j_i=1}^{J_i} v_{ij_i} a_{ij_i} \le k_v, \tag{54.4}$$

$$a_{ij_i} \in \{0, 1\}, \quad \forall i = 1, 2, \ j_i = 1, 2, \cdots, J_i. \tag{54.5}$$

The objective Eq. (54.2) minimizes the total penalty cost after loading. Equation (54.3) ensure that the total weights of the cargo do not exceed the maximum weight of the plane. Equation (54.4) guarantee that the total volumes of the cargo do not exceed the maximum volume of the plane. In Eq. (54.5), if the decision variable

$a_{ij_i} = 1$, it means the j_ith cargo of type i is loaded on the plane, otherwise $a_{ij_i} = 0$. Obviously, Eq. (54.1) satisfies the boundary conditions:

$$\text{When } x_w = 0 \text{ or } x_v = 0, U_t(x_w, x_v) = -E[C(J_i)], \tag{54.6}$$

$$\text{When } t = T, U_T(x_w, x_v) = -E[C(J_i)]. \tag{54.7}$$

Equation (54.6) means that if the received cargo has reached even exceeded the maximum available weight of the plane, the cargo booking will no longer be accepted in principle. And only the loading problem of the received cargo will be considered. Equation (54.7) represents that when the booking is over and the plane prepares to take off, the cargo booking will no longer be accepted and only the loading problem of the received cargo will be considered.

3. Optimal Conditions

$\Delta U_{it}(x_w, x_v) = U_t(x_w, x_v) - U_t(x_w - w_{it}, x_v - v_{it})$ represents the opportunity cost of accepting the cargo with type i whose weight and volume are w_{it} and v_{it} when the remaining available weight and volume are x_w and x_v in time t. Then Eq. (54.1) can be rewritten as:

$$\begin{aligned} U_t(x_w, x_v) &= \sum_{i=1,2} p_{it} \max\{U_{t+1}(x_w - w_{it}, x_v - v_{it}) + r_i w_{it}, U_{t+1}(x_w, x_v)\} + p_{0t} U_{t+1}(x_w, x_v) \\ &= \sum_{i=1,2} p_{it} \max\{r_i w_{it} - \Delta U_{i,t+1}(x_w, x_v), 0\} + U_{t+1}(x_w, x_v). \end{aligned} \tag{54.8}$$

Apparently, the optimal boundary conditions when accepting the cargo of type i are: $r_i w_{it} \geq \Delta U_{i,t+1}(x_w, x_v)$. That is, when and only when the expected revenue of accepting the cargo with type i is greater than or equal to its opportunity cost, the cargo will be accepted; otherwise, it will not be accepted.

54.4 Model Solving

We use the idea of dynamic programming dimension reduction (dynamic programming decomposition-Talluri and Van Ryzin [12]) to approximately get the optimal value of the value function $U_t(x_w, x_v)$, $1 \ll t \ll T$. Dynamic programming dimension reduction is the commonly used approximate method for solving the problems of network air transportation. The basic idea of it is to calculate the opportunity cost according to tension of the remaining available resources on each leg of the entire network, allocate the number of tickets with different levels to each leg (fare proration) and finally break down the network problem into N sub-problems in each single leg. In accordance with this idea, this paper first converts the single-leg two-dimension air cargo problem into two-leg one-dimension network problem. Then we approximately calculate the unit opportunity cost of the remaining available weight and volume of the plane in time t by dynamic programming dimension reduction.

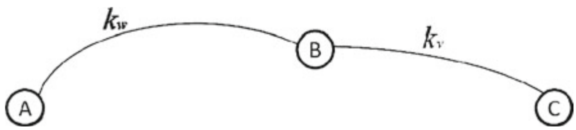

Fig. 54.1 Convert the air cargo problem

After that, we will get the expected opportunity cost of the cargo with type i which arrives at time t. Finally, we will decide whether to accept the cargo or not. The specific steps are as follows:

1. Convert the air cargo problem

As is shown in Fig. 54.1, the weight and size of the space for cargo planes are defined as leg (A, B) and leg (B, C) which the passenger planes pass through. The maximum available capacity (the maximum weight capacity) of leg (A, B) is k_w. And the maximum available capacity (the maximum volume capacity) of leg (B, C) is k_v. The unit prices of the urgent and general cargo which have arrived are equivalent to two types of the ticket prices for passengers. The actual volume and weight for a single piece of cargo is equivalent to the quantities of tickets for leg (A, B) and leg (B, C) which are purchased at one time. As a result, the single-leg two-dimension air cargo problem is converted into a two-leg one-dimension network passenger problem. The notations are re-defined as follows:

- t time for booking, $0 \leq t \leq T$. $t = 0$ expresses the start of booking. $t = T$ indicates the booking is over and the plane takes off.
- k_w, k_v maximum available capacity for leg (A, B) and leg (B, C).
- i $i = 1$ indicates the ticket of urgent class, and $i = 2$ indicates the ticket of general class.
- p_{it} states the arrival probability of demand for the ith class ticket in time period t, and $p_{0t} = 1 - \sum_{i=1,2} p_{it}$ is the probability of zero booking demand in time period t.
- r_i unit price of the ith class ticket.
- h_i unit penalty cost for the delayed transportation which is paid to the passengers who have bought the ith class tickets. $h_1 \gg r_1 > h_2 = r_2$, suppose $h_1 = M(M \to \infty)$.
- w_{it}, v_{it} the booking number of the ith class tickets on leg (A, B) and leg (B, C) in time period t, and they are also the random variables which respectively follow the distribution of ϕ_i and ψ_i.

2. Find the initial approximate solution for the unit opportunity costs of the loading weight and volume on the plane

After the converting step 1, the unit opportunity costs of the loading weight and volume on the plane are equivalent to the unit opportunity costs of resources on leg (A, B) and leg (B, C). In accordance with the assumption, at each stage t, at most one booking demand will arrive. Therefore, the number of expected booking for the ith class tickets during the whole booking period is: $n_i = \sum_{t=0}^{T_1} p_{it}$. At the same time, the booking numbers of the ith class tickets on leg (A, B) and leg (B, C) in each time period are w_{it} and v_{it}. They are the random variables which respectively follow the distribution of ϕ_i and ψ_i. According to the assumption, the distributions do not change over time, so $E[w_{it}] = E[w_i] = \int_0^{+\infty} \phi_i(l)ldl$, $E[v_{it}] = E[v_i] = \int_0^{+\infty} \psi_i(l)ldl$. Here, ϕ_i and ψ_i are the density functions which respectively correspond to the distribution function ϕ_i and ψ_i: $\phi_i(d) = \int_{-\infty}^{d} \phi_i(l)ldl$, $\psi_i(d) = \int_{-\infty}^{d} \psi_i(l)ldl$. Apparently, according to the problem, when $l \leq 0$, $\phi_i(l) = \psi_i(l) = 0$.

The multi-objective stochastic programming model with expected value which is used to solve the loading problem above is developed here:

$$\max E\{\sum_{i=1,2} f_i(x_i) - C(x_i), -C(x_i)\},$$
$$\text{s.t.} \begin{cases} x_i \geq 0,\ i = 1, 2, \\ E[f_i(x_i)] = r_i \cdot \min\{x_i, n_i\} \cdot E[x_i]. \end{cases} \tag{54.9}$$

Substituting the above Eqs. (54.2)–(54.5) into Eq. (54.9), it can be converted as:

$$\max d_1^+ - d_1^- - d_2^+ + d_2^-, \tag{54.10}$$

Subject to

$$\sum_{i=1,2} \{r_i \cdot \min\{x_i, n_i\} \cdot E[w_i] - \sum_{j_i=1}^{\min\{x_i,n_i\}} h_i E[w_i](1 - a_{ij_i})\} - d_1^+ + d_1^- = 0, \tag{54.11}$$

$$\sum_{j_i=1} \min\{x_i, n_i\} h_i E[w_i](1 - a_i j_i) - d_2^+ + d_2^- = 0, \tag{54.12}$$

$$\sum_{i=1,2} \sum_{j_i=1} \min\{x_i, n_i\} E[w_i] a_i j_i \leq k_w, \tag{54.13}$$

$$\sum_{i=1,2} \sum_{j_i=1} \min\{x_i, n_i\} E[v_i] a_i j_i \leq k_v, \tag{54.14}$$

$$x_i, d_i^{\pm} \geq 0, a_i j_i \in \{0, 1\}, \quad \forall i = 1, 2,\ \ j_i = 1, 2 \cdots, x_i. \tag{54.15}$$

The objective Eq. (54.10) maximizes the total expected net revenue after the acceptance of booking and transportation while minimizing the penalty cost for the delayed transportation. Equation (54.13) indicate that the expected transportation demands on leg (A, B) do not exceed its maximum transportation capacity. Equation (54.14) ensure that the expected transportation demands on leg (B, C) do not exceed its maximum transportation capacity. In Eq. (54.15), the decision variable x_i represents the total number of the accepted bookings for the ith class tickets. $a_{ij_i} = 1$ means the booking of the j_ith tickets with type i is accepted, otherwise $a_{ij_i} = 0$.

To make the model easier to solve, set a_i as the total number of orders for the ith class tickets which have been transported, then the model above can be simplified to:

$$\max d_1^+ - d_1^- - d_2^+ + d_2^-, \quad (54.16)$$

Subject to

$$\sum_{i=1,2} E[w_i] \cdot \{r_i x_i - h_i(x_i - a_i)\} - d_1^+ + d_1^- = 0, \quad (54.17)$$

$$\sum_{i=1,2} h_i E[w_i](x_i - a_i) - d_2^+ + d_2^- = 0, \quad (54.18)$$

$$\sum_{i=1,2} E[w_i]a_i \leq k_w, \quad (54.19)$$

$$\sum_{i=1,2} E[v_i]a_i \leq k_v, \quad (54.20)$$

$$a_i - x_i \leq 0, \quad (54.21)$$

$$x_i - n_i \leq 0, \quad (54.22)$$

$$a_i, x_i, d_i^{\pm} \geq 0 \quad \forall i = 1, 2. \quad (54.23)$$

Equations (54.16)–(54.20) correspond to Eqs. (54.10)–(54.14) which have not be simplified. The meaning of the decision variable x_i is unchanged. Equation (54.21) ensure that the total number of the transported tickets does not exceed the total number of the received orders. Equation (54.22) states that the expected total number of the accepted orders does not exceed the expected total number of the received orders.

It is very easy to get the optimal solution of the model π_w, π_v and the optimal solution of the corresponding dual problem π_w, π_v. That is, the initial approximate solution of unit opportunity cost for the resources (the loading weight and volume on the plane) on leg (A, B) and leg (B, C). Particularly, from Eqs. (54.2), (54.12) and (54.18), it is easy to know:

$$E[C(J_i)] = E[C(x_i)] = \sum_{i=1,2} h_i E[w_i](x_i - a_i) = d_2^+ - d_2^-. \quad (54.24)$$

Therefore, substituting the optimal solution of decision variables x_i, a_i and x_i, a_i in the simplified stochastic programming model into Eq. (54.24), the approximate expected penalty cost for transportation $E[C(J_i)]$ can be obtained.

3. Calculate the prorated cargo rate for all types of cargo

The prorated cargo rate for all types of cargo is the prorated resource rate for all types of tickets on the legs. Set $pcr_i j$ as the prorated resource rate for the ith class $(i = 1, 2)$ of tickets on the leg j $(j = w, v)$, then: $pcr_{ij} = \max\{0, r_i - \pi_l|_{l\in\{w,v\},l\neq j}\}$. Its economic explanation is: when accepting the ith class of cargo and taking out the expected opportunity cost of the occupied weight (volume) of the plane, it is the expected revenue generated by the occupied weight (volume) of the plane. Obviously, when pcr_{ij} is higher, the resources on leg j are more precious as to the ith class of cargo.

4. Convert Eq. (54.1) into two one-dimension dynamic programming models

The prorated cargo rate for all types of cargo is pcr_{ij}. Equation (54.1) can be converted into the following two one-dimension dynamic programming models to solve:

$$U_{wt} = \sum_{i=1,2} p_{it} \max\{Uw, t+1(x_w - 1) + pcr_{iw}, U_{i,t+1}(x_w)\} + p_{0t} U_{w,t+1}(x_w), \tag{54.25}$$

$$U_{vt} = \sum_{i=1,2} p_{it} \max\{Uv, t+1(x_v - 1) + pcr_{iv}, U_{i,t+1}(x_v)\} + p_{0t} U_{v,t+1}(x_v). \tag{54.26}$$

Similarly, Eqs. (54.25) and (54.26) satisfy the boundary conditions: When $x_j = 0, U_{jt}(x_j) = E[C(J_i)], j = w, v$, When $t = T, U_{jT}(x_j) = E[C(J_i)],\ j = w, v$.

5. Calculate the opportunity costs of the loading weight and volume on the plane

Set $\triangle U_{wt}(x_w)$ as the unit opportunity cost of the loading weight on the plane when the remaining weight is x_w at time t, then: $\triangle U_{wt}(x_w) = U_{wt}(x_w) - U_{wt}(x_w - 1)$. Similarly, set $\triangle U_{vt}(x_v)$ as the unit opportunity cost of the loading volume on the plane when the remaining volume is x_v at time t, then: $\triangle U_{vt}(x_v) = U_{vt}(x_v) - U_{vt}(x_v - 1)$.

6. Calculate the expected opportunity costs for all types of cargo

The unit opportunity costs of the loading weight and volume on the plane are $\triangle U_{wt}(x_w)$ and $\triangle U_{vt}(x_v)$ when the remaining weight and volume are x_w and x_v at time t. Then the expected opportunity cost of the ith class cargo with weight w_{it} and volume v_{it} which arrives at time t is: $EC = \triangle U_{wt} \cdot w_{it} + U_{vt} \cdot v_{it}$. Therefore, the optimal boundary conditions for accepting the cargo are: $r_i w_{it} - EC \geq 0$. That is, when and only when the expected revenue of accepting the cargo with type i is greater than or equal to its opportunity cost, the cargo will be accepted; otherwise, it will not be accepted.

54.5 Simulation Example

We use the simulation example to illustrate the implementation processes of the strategies for the air cargo inventory control when considering the differences in transport time for the cargo. And the following problems are examined:

1. Comparing with the traditional first-come-first-transported strategy, is the strategy for the air cargo inventory control when considering the differences in transport time for the cargo better?
2. In the implementation process, is there a regular pattern for this inventory control strategy?

54.5.1 Numerical Example

Flight A starts booking 48 h in advance. The maximum loading weight and volume of it are 15,000 kg and 100 m^3. The unit transport prices for the urgent cargo and the general cargo are 3.00 and 1.00 Yuan per kg. Usually, the urgent cargo cannot be delayed while the general cargo can be delayed, so the penalty cost of the urgent cargo is 100.00 Yuan per kg while the penalty cost of the general cargo is 1.00 Yuan per kg. In the time interval for booking, the average number of the arrived orders is 245. The urgent cargo accounts for 12 % of the orders which the general cargo accounts for 88 %. The weight and volume of the urgent cargo respectively follow the gamma distribution $\Gamma(3, 16)$ and $\Gamma(3, 0.0842)$. The weight and volume of the general cargo respectively follow the gamma distribution $\Gamma(4, 40)$ and $\Gamma(4, 0.2105)$. Suppose that in the whole time interval for booking, the arrivals of both the urgent cargo and general cargo follow Poisson distribution. So the unit opportunity cost of the loading weight and volume on the plane during the peak seasons can be obtained, which is shown in Table 54.1.

Based the data in Table 54.1, the opportunity cost of the arrived cargo can be calculated according to Step 6 in Sect. 54.4. The detailed implementation processes of the strategy for inventory control will be given later (Table 54.2).

54.5.2 Simulation Strategy

In this section we conduct the simulation for the whole booking processes of Flight A by applying the traditional first-come-first-transported strategy and the proposed strategy (referred to as inventory control strategy) in this paper. Then the differences between the two strategies are compared. By running the simulation program in Matlab for 100 times, the results can be obtained as follows:

The average net revenue of the first-come-first-transported strategy is 16,223.84 Yuan. The average weight rate of this strategy is 99.96 % and the average volume

Table 54.1 The numerical value of opportunity cost of weight and volume of air cargo

Time period	Remaining weight	Expected revenue from the weight	Opportunity cost of the weight	Remaining volume	Expected revenue from the volume	Opportunity cost of the volume
1	10	27.00	3.00	10	18.00	2.00
1	20	56.94	2.97	20	37.95	1.97
1	30	83.23	2.11	30	54.31	1.12
1	40	97.48	1.08	40	58.65	0.08
1	50	107.63	1.00	50	58.81	0.00
1	60	117.63	1.00	60	58.81	0.00
1	70	127.63	1.00	70	58.81	0.00
1	80	137.63	1.00	80	58.81	0.00
1	90	147.63	1.00	90	58.81	0.00
1	100	157.63	1.00	100	58.81	0.00
2	10	27.00	3.00	10	18.00	2.00
2	20	56.94	2.97	20	37.94	1.97
2	30	83.14	2.09	30	54.22	1.10
...	...	...	...	...	...	...

Table 54.2 The results of simulation

Item	Average net revenue	Average weight rate (%)	Average volume rate (%)
First-come-first-transported strategy	16223.84	99.96	79.72
Inventory control strategy	17296.32	99.79	78.31
Differences	6.67 %	−0.17	−1.76

rate is 79.72 %. The average net revenue of the inventory control strategy is 17296.32 Yuan which shows a 6.67 % increase to the first-come-first-transported strategy. The average weight rate of this strategy is 99.79 % and the average volume rate is 78.31 %, which is similar to the former strategy (Table 54.2).

In particular, by applying the first-come-first-transported strategy, the average number of accepted tickets for the general cargo is 90.6 which accounts for 87 % of all the tickets, and the average number of accepted tickets for the urgent cargo is 13.5 which accounts for 13 %. The accepted rate is almost the same as the arrival rate. But by applying the inventory control strategy, the average number of accepted tickets for the general cargo is 90 which accounts for 79 % of all the tickets, and the average number of accepted tickets for the urgent cargo is 24 which accounts for 21 %. The accepted rate of the urgent cargo increases a lot. And 4.7 % of the general cargo is delayed.

54.6 Conclusion

Air cargo revenue management has gradually become an important method to enhance the competitive advantages of the air companies. This paper develops a dynamic programming model which takes the differences in transport time for the cargo into account and obtains the optimal inventory control strategy for a single leg air cargo revenue management with two types of cargo. Compared with the traditional first-come-first-transported strategy, the proposed inventory control strategy can increase the revenue from two aspects: first, when receiving the orders, the urgent cargo with higher price has a higher priority; second, when transporting the cargo, a small proportion of the general cargo should be delayed in order to ensure all the urgent cargo are transported on time and the perception of the customers are not affected. This paper only focuses on the single leg air cargo revenue management problem with two types of cargo. It is more complicated for the multi-leg problem with multiple types of cargo. In order to better meet the needs of the air cargo companies, further research should be conducted in this field.

Acknowledgments The work was supported by the Natural Science Foundation of China (No. 71172197, 70771068, 70440007).

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Chapter 55
Profit Allocation Mechanism of Supply Chain with Bilateral Asymmetric Costs Information

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Abstract This paper investigates the problem of profit allocation under bilateral asymmetric information environment. More specifically, we consider a supply chain consisting of one risk-neural manufacturer and one risk-neural retailer for an innovation product. In order to facilitate the cooperation, the manufacturer and the retailer commit to share their private information under a commitment contract based on the AGV (d'Aspremont and Gerard-Varet) mechanism. We analyze the relationship between the expected information rents and the realized supply chain profit, and discuss the allocation rule implementation under three different cases by introducing the R-S-K negotiation. We show that the commitment contract can achieve truthful information revealing and allocate the ex post profit reasonably. Finally, one numerical example is presented to explain the main results.

Keywords Supply chain · Profit allocation · Bilateral asymmetric information · AGV mechanism · Information rents

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_55,

55.1 Introduction

The collaboration between supply chain members can significantly improve supply chain's performance. However, the individual decisions based on information sharing fully are often unrealistic. The fact is that the supply chain members are separate and independent economic entities, they will act independently and opportunistically to optimize their individual benefits depending largely on their acquired information. In this case, an action plan should be complemented with an incentive scheme that can allocate the benefits of coordination among the supply chain members so as to align their objectives of coordination [14].

This paper focuses on the incentive mechanism designing, especially for the allocation rules implementation under asymmetric information case. For a supply chain consisting of one manufacturer and one retailer, neither of them can control the entire supply chain. Each supply chain member has its own state of information and decisions that can be made use to optimize its own interest. Thus, an ex ante incentive contract is needed to coordinate their action by allocating the supply chain's profits. While some scholars have investigated the allocation rule designing under the bilateral asymmetric information case [17, 19], we have a different focus.

Our contributions to the literature will be two aspects: first, based on the basic asymmetric costs information model [19], we analyze three relationships between the realized supply chain profit and the sum of expected information rents. Second, by using the thought of R-S-K bargaining solution [12, 15], we discuss three cases to implement the allocation rule.

55.2 Literature

This paper can be regarded as a study of supply chain incentive mechanism designing. In order to highlight our contributions, we review only the literature that is particularly relevant to our study.

Information sharing mechanism has attracted substantial attention by many scholars [13, 16, 20]. However, a few researchers were motivated to explore supply chain models under the bilateral asymmetric information scenario. Chatterjee and Samuelson [5] analyze that the seller and the buyer achieve bilateral asymmetric information by bargaining strategy, and their private information is the evaluation of commodity price. Zhang and Luo [21] explore the trade credit in coordinating supply chain under bilateral information senior. In the proposed model the manufacturer possesses the private information regarding its own capital cost while the retailer has the private information about the budget constraint or capital cost. Esmaeili and Zeephongsekul [8] consider a supply chain, in which the buyer and seller have the private information about demand information and purchase costs respectively. Wang et al. [18] examine the supply chain efficiency under the bilateral information case. Some bilateral asymmetric information problem can be seen in the analysis of auction [3, 6, 7, 10]. Wang and Wang [17] consider a bilateral asymmetric information case and propose an ex ante informal contract to coordinate the supply chain. Wang et al. [19] analyze the bilateral cost asymmetric information sharing by the virtue of the AGV mechanism [1, 2], and design a set of improved transfer payments to coordinate the supply chain.

In order to align the supply chain member's objectives of coordination, some incentive profit sharing mechanisms have also been proposed. Under this proposal, the system performance is first optimized and the resultant benefit is then shared between the manufacturer and the buyer. Its implementation, however, depends on the development of a profit sharing scheme that is acceptable to both parties. Goyal [9] proposed for the manufacturer and buyer to share the coordination benefit proportionally according to their costs. Joglekar and Tharthare [11] allocated the profit by making the buyers pay for the order processing cost they impose on the vendor every time they order.

With a bilateral asymmetric information case, allocation rules based on the information rents are firstly proposed by Wang and Wang [17]. In the works [17, 19], the expected information rents denote the negotiation power. However, they have not revealed the relationship between the information rents. Also, they design a set of compensate parameters related to the allocation rule, but the parameters are relatively complicated and con not easily implemented in practice. Thus, in this paper, the relationship between the information rents and the supply chain as well as allocation rule implement are our focus.

This paper is organized as follows. Section 55.2 reviews literature in the areas of information revealing mechanism designing. Section 55.3 introduces the model assumption and constructs the basic model. Section 55.5 analyzes the relationship between the information rents and the supply chain's profit, then examines the implementation of the allocation rule. Section 55.7 provides a numerical example to illustrate the main results. Section 55.8 concludes this paper.

55.3 Model Assumptions and Notation

Consider a two-stage supply chain consisting of one manufacturer and one retailer, and both are risk neutral. Prior to production, the manufacturer and the retailer commit a formal agreement to ensure the latter trading. The formal agreement includes the trading quantity depending on the production cost and the retail cost, which are not clear at this point and the corresponding transfer payments. When the sample product is finished, the true production cost and retail cost can be obtained by the manufacturer and the retailer, thus the production cost and retail cost are their private information respectively. Then the two firms share their acquired private information to determine the trading quantity according the ex ante informal agreement (The sequence of events can be seen in Fig. 55.1). The retailer buys the product from the upstream manufacturer and sells it to a market in which demand is stochastic.

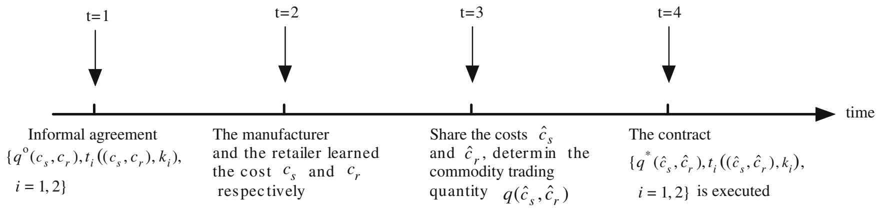

Fig. 55.1 Timing of the contracting game

The manufacturer and the retailer are both risk neutral. In order to simplify notation, without loss of generality we also assume the goodwill cost and the salvage cost are both zero.

The notation used in our study is summarized below:

p	Selling price per unit,
$q^*(\cdot)$	Optimal commodity trading quantity in the asymmetric information case,
$q^0(\cdot)$	Optimal commodity trading of the supply chain in the symmetric information case,
$t_1(\cdot)$	Transfer payment to the manufacturer,
$t_2(\cdot)$	Transfer payment to the retailer,
$c_s, \hat{c}_s$	Manufacturer's true unit production cost and announcing unit production cost, belong to $[\underline{c}_s, \bar{c}_s]$,
$c_r, \hat{c}_r$	Retailer's true unit retail cost and announcing unit retail cost, belong to $[\underline{c}_r, \bar{c}_r]$,
$F_1(\cdot),\ f_1(\cdot)$	Strictly increasing distribution function and corresponding density function of c_s,
$F_2(\cdot),\ f_2(\cdot)$	Strictly increasing distribution function corresponding density function of c_r,
$E_{c_r}(\cdot)$	Expectation function with respect to $F_2(\cdot)$,
$E_{c_s}(\cdot)$	Expectation function with respect to $F_1(\cdot)$,
$E_{c_r,c_s}(\cdot)$	Double expectations function with respect to $F_1(\cdot)$ and $F_2(\cdot)$,
$D > 0$	Market stochastic demand during the selling season,
$G(\cdot), g(\cdot)$	Strictly increasing distribution function and corresponding density of stochastic demand,
$S(q(\cdot))$	Expected sales for retailer, equals $\min(q(\cdot), D)$,
$\Pi(\cdot)$	Profit function of the total supply chain,
$\Pi_1(\cdot)$	Manufacturer's profit function,
$\Pi_2(\cdot)$	Retailer's profit function.

As usual, we also assume that $\underline{c}_s + \underline{c}_r < p < \bar{c}_s + \bar{c}_r$ in order not to incur negative profit of the system or parties.

55.4 Model Based on AGV Mechanism

This subsection presents one supply chain model with bilateral asymmetric costs information based on the AGV mechanism.

Let $\Pi_1(q(\hat{c}_s, \hat{c}_r), c_s)$ and $\Pi_2(q(\hat{c}_s, \hat{c}_r), c_r)$ be the profit functions of manufacturer and retailer respectively, which are given by:

$$\Pi_1(q(\hat{c}_s, \hat{c}_r), c_s) = -c_s q(\hat{c}_s, \hat{c}_r)) + t_1(\hat{c}_s, \hat{c}_r), \tag{55.1}$$

$$\Pi_2(q(\hat{c}_s, \hat{c}_r), c_r) = pS(q(\hat{c}_s, \hat{c}_r)) - c_r q(\hat{c}_s, \hat{c}_r) + t_2(\hat{c}_s, \hat{c}_r). \tag{55.2}$$

According to the AGV mechanism, the transfer payments can be written as:

$$\begin{aligned} t_1(\hat{c}_s, \hat{c}_r) = & \int_{\underline{c}_r}^{\bar{c}_r} \left[pS((q(\hat{c}_s, c_r)) - c_r q(\hat{c}_s, c_r)\right] f_2(c_r) dc_r \\ & + \int_{\underline{c}_s}^{\bar{c}_s} c_s q(c_s, \hat{c}_r) f_1(c_s) dc_s, \end{aligned} \tag{55.3}$$

$$\begin{aligned} t_2(\hat{c}_s, \hat{c}_r) = & -\int_{\underline{c}_r}^{\bar{c}_r} \left[pS((q(\hat{c}_s, c_r)) - c_r q(\hat{c}_s, c_r)\right] f_2(c_r) dc_r \\ & - \int_{\underline{c}_s}^{\bar{c}_s} c_s q(c_s, \hat{c}_r) f_1(c_s) dc_s. \end{aligned} \tag{55.4}$$

The transfer payments require essentially that each party appropriates the expected externality he actions impose on other party. The expected profits of the agents are given by:

$$\begin{aligned} E_{c_r}\left(\Pi_1\left(q(\hat{c}_s, c_r), c_s\right)\right) = & E_{c_r}\left[pS(q(\hat{c}_s, c_r)) - c_r q(\hat{c}_s, c_r) - c_s q(\hat{c}_s, c_r)\right] \\ & + E_{c_r, c_s}(c_s q(c_s, c_r)), \end{aligned} \tag{55.5}$$

$$\begin{aligned} E_{c_s}\left(\Pi_2\left(q(c_s, \hat{c}_r), c_r\right)\right) = & E_{c_s}[pS(q(c_s, \hat{c}_r)) - c_r q(c_s, \hat{c}_r) - c_s q(c_s, \hat{c}_r)] \\ & - E_{c_s, c_r}[pS(q(c_s, c_r)) - c_r q(c_s, c_r)]. \end{aligned} \tag{55.6}$$

Proposition 55.1 *The transfer payments can induce the manufacturer and the retailer share their private information truthfully, i.e.,*$\hat{c}_s = c_s, \hat{c}_r = c_r$.

Proposition 55.1 states that with the transfer payments each party is induced to internalize the whole supply chain's decision and is effectively maximizing the system's objective.

55.5 The Information Rents and Allocation Rule

55.5.1 Information Rents

In general, the allocation proportion also denotes the negotiation power in the economic game. While in the unilateral asymmetric information problem of the supply chain, the information rent for revealing information truthfully is seen as a reservation profit, and it can be seen as the informed party's negotiation power. Thus, we can define an allocation proportion of supply chain's profit based on the manufacturer and retailer's expected information rents at ex ante stage. Since the manufacturer and the retailer have their information advantages, neither of them can control the supply chain system, thus, this allocation rule is acceptable for two parties and is reasonable.

We first compute the two firms' expected information rents. According to the Proposition 55.1, announcing cost information truthfully ($\hat{c}_s = c_s$) means that the following formula is satisfied.

$$E_{c_r}\Pi_1(q(c_s, c_r), c_s) \geqslant E_{c_r}\Pi_1(q(\hat{c}_s, c_r), c_s). \tag{55.7}$$

In the similar way, for the retailer it holds that:

$$E_{c_s}\Pi_2(q(c_s, c_r), c_r) \geqslant E_{c_s}\Pi_2(q(c_s, \hat{c}_r), c_r). \tag{55.8}$$

By the Eqs. (55.7) and (55.8), we have the proposition below.

Proposition 55.2 *Constraints Eqs. (55.7) and (55.8) can be reduced to two differential equations and two monotonicity constraints,*

$$\frac{\partial \Pi_1(c_s, c_r)}{\partial c_s} = -q(c_s, c_r), \frac{\partial \Pi_2(c_s, c_r)}{\partial c_r} = -q(c_s, c_r),$$
$$E_{c_r}\frac{\partial q(c_s, c_r)}{\partial c_s} \leqslant 0, E_{c_s}\frac{\partial q(c_s, c_r)}{\partial c_r} \leqslant 0.$$

By the differential equations in Proposition 55.2, we can obtain that

$$\Pi_1(c_s, c_r) = \Pi_1(\bar{c}_s, c_r) + \int_{c_s}^{\bar{c}_s} q(s, c_r)ds, \tag{55.9}$$

$$\Pi_2(c_s, c_r) = \Pi_2(c_s, \bar{c}_r) + \int_{c_r}^{\bar{c}_r} q(c_s, t)dt. \tag{55.10}$$

Equations (55.9) and (55.10) can be regarded as the information rents for the manufacturer and retailer [4]. Thus the expected information rents of the supplier and the retailer at ex ante age are

$$E_{c_s,c_r}\left(\Pi_1(c_s,c_r)\right)=E_{c_s,c_r}\left(\Pi_1(\bar{c}_s,c_r)\right)+E_{c_s,c_r}\left(\int_{c_s}^{\bar{c}_s} q(s,c_r)ds\right), \tag{55.11}$$

$$E_{c_s,c_r}\left(\Pi_2(c_s,c_r)\right)=E_{c_s,c_r}\left(\Pi_2(c_s,\bar{c}_r)\right)+E_{c_s,c_r}\left(\int_{c_r}^{\bar{c}_r} q(c_s,t)dt\right). \tag{55.12}$$

As usual, we can assume that at the optimum the least efficient manufacturer and retailer receives his reservation utilities: $E_{c_s,c_r}\left(\Pi_1(\bar{c}_s,c_r)\right)=0$ *and* $E_{c_s,c_r}\left(\Pi_2(c_s,\bar{c}_r)\right)=0$. *These two formulas exclude the case that one part with the highest cost enters the trade.*

Definition 55.1 In the model of bilateral asymmetric information, the allocation rule of the total supply chain is given as $K_1=H_1/(H_1+H_2)$, $K_2=H_2/(H_1+H_2)$, where $H_1=E_{c_s,c_r}\left(\Pi_1(c_s,c_r)\right)$, $H_2=E_{c_s,c_r}\left(\Pi_2(c_s,c_r)\right)$.

55.6 Implementation of Profit Allocation

Note that to avoid misrepresenting the private information, the manufacturer and the retailer must get information rents, but the sum of the expected rents may exceed the supply chain profit in some contingencies. This is similar to the conclusion discussed in bilateral trade by Bolton and Dewatripont [4]. Thus, the relationship between the realized total supply chain profit and the sum of expected information rents can be expressed as follows: $\lambda E_{c_s,c_r}\left[\Pi_1(c_s,c_r)+\Pi_2(c_s,c_r)\right]=\left[\Pi_1(\hat{c}_s,\hat{c}_r)+\Pi_2(\hat{c}_s,\hat{c}_r)\right]$. It is equivalent to:

$$\lambda E_{c_s,c_r}\left[\int_{c_s}^{\bar{c}_s} q(s,c_r)ds+\int_{c_r}^{\bar{c}_r} q(c_s,t)dt\right]=\left[pS(q(\hat{c}_s,\hat{c}_r))-(c_r+c_s)q(\hat{c}_s,\hat{c}_r)\right]. \tag{55.13}$$

Here λ is a nonzero parameter. If $\lambda<1$, the total expected rents are larger than the realized total chain profit; $\lambda=1$, the total expected rents equal the realized total chain profit; $\lambda>1$, the total expected rents are less than the realized total chain profit. The different cases can be illustrated from Figs. 55.2, 55.3 and 55.4. The line segment CD denotes the realized chain's profit, and the point "O" denotes the reference point of expected information rents. If the point of expected information rents is out of the region OCD, it means that $\lambda<1$ (Fig. 55.2); If the point of expected information rents is in the region OCD, it means that $\lambda>1$ (Fig. 55.3).

Now we analyze how to allocate the ex post total chain's profit by the manufacturer and retailer according the allocation proportion, K_1, K_2. As in Fig. 55.2, by using the idea of R-S-K bargaining solution [12, 15], we connect profit reference point "O" and expected rents point "A", thus line OA is the corresponding allocation

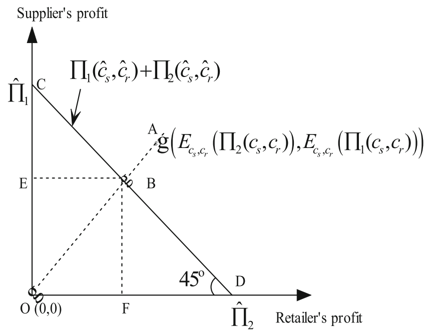

Fig. 55.2 Relationship between the chain's profit and the expected information rents ($\lambda < 1$)

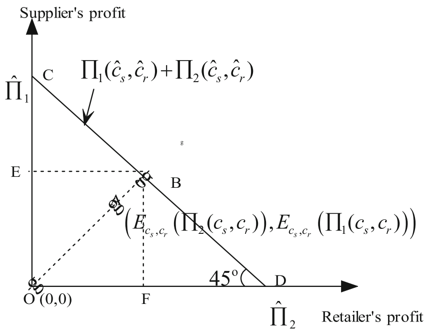

Fig. 55.3 Relationship between the chain's profit and the expected information rents ($\lambda > 1$)

route. Compute the slope of the line OA, $k_{OA} = K_1/K_2$, and we can easily get $BC/BD = K_2/K_1$. Consequently, the realized total chain's profit is divided into two parts, for the manufacturer is line segment BD and for the retailer is line segment BC. In the similar way, in Fig. 55.3, we can connect the point O and point A, and extend into line segment CD at point B. Thus, we also get that $BC/BD = K_2/K_1$. In Fig. 55.4, the expected information point B is on the line segment CD. Hence we can easily get the allocation proportion which is independent to the slope of the line OB.

Actually, in the current asymmetric information model based on the AGV mechanism, both the manufacturer and retailer announce their true costs information simultaneously. This action coordinates the supply chain as well as realizes their individuals' optimal profits. By the allocation rule, the profits of the manufacturer and the retailer are:

$$\tilde{\Pi}_1 = K_1(\Pi_1 + \Pi_2) = K_1\left(pS(q(c_s,c_r)) - c_r q(c_s,c_r) - c_s q(c_s,c_r)\right), \quad (55.14)$$

$$\tilde{\Pi}_2 = K_2(\Pi_1 + \Pi_2) = K_2\left(pS(q(c_s,c_r)) - c_r q(c_s,c_r) - c_s q(c_s,c_r)\right). \quad (55.15)$$

Fig. 55.4 Relationship between the chain's profit and the expected information rents (λ = 1)

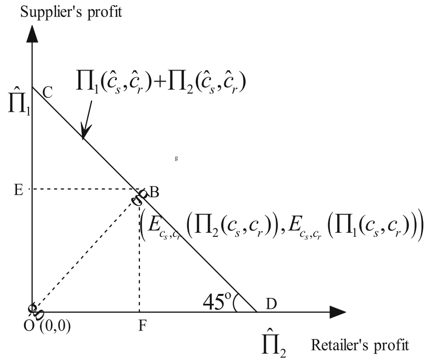

Table 55.1 The relationship between the sum of expected information rents and the realized chain profit ($c_r = 1.5$)

c_s	c_r	$H_1 + H_2$	$\Pi(c_s, c_r)$	$K_1\ \Pi(c_s, c_r)$	$K_2\ \Pi(c_s, c_r)$	λ
2.5	1.5	60.41	100.00	65.50	34.50	> 1
3.4	1.5	60.41	60.41	39.57	20.84	= 1
3.5	1.5	60.41	56.25	36.84	19.41	< 1

55.7 Numerical Example

In this section, we present the numerical results that allocate the realized chain's profit in three different cases.

Assume that $p = 8$, $c_s, \hat{c}_s \in [2, 4] c_r, \hat{c}_r \in [1, 2]$ and $y \in [0, 100]$.F_1, F_2, G are uniform distribution functions. Then $F_1(c_s) = (c_s - 2)/2$, $f_1(c_s) - 1/2$, $F_2(c_r) = c_r - 1$, $f_2(c_r) = 1$, $G(y) = y/100$. We can easily have the order quantity $q^*(c_s, c_r) = 100[1 - (c_s + c_r)/8]$. The expected information rent for the manufacturer is $H_1 = 39.58$, and the expected information rent for the retailer is $H_2 = 20.83$. Thus the allocation rule is $K_1 = 0.655$, $K_2 = 0.345$. The sum of expected information rents is $H_1 + H_2 = 60.41$, and the realized total supply chain profit is $\Pi(c_s, c_r) = 6.25[8 - (c_s + c_r)]^2$.

Table 55.1 illustrates the relationship between the sum of expected information rents and the realized chain's profit for $c_r = 1.5$. Three cases exist in Table 55.1, which verify the analysis in Sect. 55.4. As shown in the table, for $c_s + c_r < 4.9$, the total chain's profit is larger than the sum of expected information rents, whereas the total chain's profit is less than the sum of expected information rents for $c_s + c_r > 4.9$.

Table 55.2 presents the variation of the total chain's profit and the individual's profit for different production cost and retail cost. The chain's profit decreases with the increasing production cost and the retail cost, which can be seen on Fig. 55.5. This will raises the case that the supply chain's profit is less than the sum of information rents. As shown in Table 55.2, if $c_s + c_r >= 3.4 + 1.7$, the two parties' information

Table 55.2 The profits of the supply chain and the supply chain members

c_s	c_r	$H_1 + H_2$	$\Pi(c_s, c_r)$	$K_1\ \Pi(c_s, c_r)$	$K_2\ \Pi(c_s, c_r)$	λ
2.2	1.1	60.41	138.60	90.43	47.63	> 1
2.4	1.2	60.41	121.00	79.26	41.76	> 1
2.6	1.3	60.41	105.06	68.82	36.25	> 1
2.8	1.4	60.41	90.25	59.11	31.14	> 1
3.0	1.5	60.41	76.56	50.15	26.41	> 1
3.2	1.6	60.41	64.00	41.92	22.08	> 1
3.4	1.7	60.41	52.56	34.43	18.13	< 1
3.6	1.8	60.41	42.25	27.67	14.58	< 1
3.8	1.9	60.41	33.06	21.66	11.40	< 1

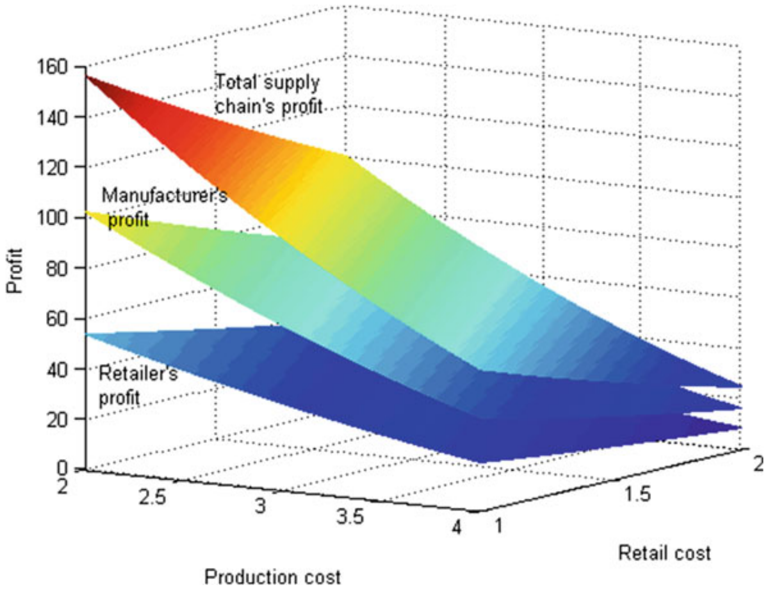

Fig. 55.5 The profit variation with the production cost and retail cost

rents can not be ensured. Thus, the profit can be allocated using the method shown in Fig. 55.2.

55.8 Conclusions and Future Research

The bilateral asymmetric information case in many supply chains is very common, and it is worthwhile to investigate for improving performance and coordinating the supply chain. This paper addresses the supply chain with bilateral asymmetric costs information.

We first construct a model based on the AGV mechanism and propose an ex ante informal contract. We find that the proposed contract associated with the AGV mechanism is able to reveal the costs information truthfully. Meanwhile, the manufacturer and retailer will maximize their individual's profit by announcing the true costs information.

We then propose an allocation rule based the expected information rents, which is acceptable for each party. Additionally, we analyze three relationships between the realized chain's profit and the expected information rents. By using the idea of R-S-K bargaining solution, the realized total chain's profits are allocated reasonably.

Our research yields some key managerial insights that can be applied generally despite the restrictive assumptions that the costs information are asymmetric for the manufacturer and retailer. Additionally, some factors, such as leftover inventory and lost-sales, have been omitted for simplicity. Further research can extend our model to include the asymmetric market demand information and leftover inventory.

Acknowledgments This work was supported by the Foundation of National Nature Science of China (Grant NO. 71071103) and the Ministry of Education, Humanities and Social Science Planning Fund for the Western and Frontier (NO. 13XJC630014), and the Dr. Innovation Research for the Central University (NO. 13NZYBS08).

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Chapter 56
Lean and Green Supply Chain Performance: A Balanced Scorecard Perspective

Susana Duarte and Virgílio António Cruz-Machado

Abstract The performance evaluation has become an important subject to get competitive advantage on supply chain. New business paradigms as lean and green are able to develop improvements on the supply chain performance. To get a balanced performance measurement system, a balanced scorecard (BSC) may be developed. This study is motivated by the lack of evidence on the lean and green supply chain performance through a BSC framework. The purpose of this study is to explore how to reach benefits on supply chain performance, considering the lean and green performance measures through the traditional BSC perspectives. To attain the paper objective in a first stage a literature review was carried out, to provide a comprehensive understanding of how the BSC can incorporate the lean and green supply chain performance measures. Next, a conceptual framework was developed to investigate how lean and green initiatives can affect the supply chain performance, using a cause-and-effect BSC approach. It is possible to recognize that lean and green initiatives influence the linkages between performance measures. These linkages in the scorecard are an example of how to evaluate the organization's supply chain.

Keywords Lean supply chain · Green supply chain · Balanced scorecard · Performance measurement

56.1 Introduction

Several factors are becoming increasingly critical and may influence the business environment namely, globalization, technology innovation, new organizational skills, design of products and services, customized customer demand, or environmental

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_56,

protection and resource scarcity [3, 4, 21]; these factors affect organization's supply chains in various ways, resulting in new requirements on supply chain management [3]. The deployment of the business paradigms lean and green can be seen as opportunities for supply chain improvement. The principal subject of these paradigms is that lean supply chain focused on continuous processes improvement, searching for simplification, reducing activities that do not add value and, at the same time, reduce waste [24]; and green supply chain pretends to minimize environmental impacts while reduce environmental wastes in organizations [26].

Supply chains must be viewed as a system that needs to be developed and improved therefore a performance measurement system is needed; through the performance measurement, organization can assess whether its supply chain has improved or degraded [15]. However, for the authors [1] the performance measurement does not receive adequate consideration in supply chain management.

To date there is a small amount of literature about lean and green supply chain performance, the lean and green measures and the accomplishment of operational, tactical and strategy objectives on supply chain management. In addition, there is a lack of evidence on carrying out a balanced approach to performance measurement, using the balanced scorecard (BSC) to evaluate the lean and green supply chain performance.

Based on these viewpoints, this paper aims to present a study to understand the lean and green supply chain performance evaluation through a BSC. A causal diagram was used to represent the linkages between each measure from the four perspectives. The core measures selected to evaluate supply chain performance are based on lean and green core measures namely, "profitability and revenues", "cost", "market share", "customer satisfaction", "productivity", "waste reduction", "supplier side management", "information management", "employee morale and satisfaction" and "employee's education and training". Hypothetical linkages between measures were identified and proposed. The conceptual framework looks at the literature in order to investigate and confirm these linkages.

The remainder of this paper is organized as follows: in Sect. 56.2, a literature review on lean and green supply chain performance; in Sect. 56.3, a cause-and-effect diagram was designed and explores the linkages between performance measures on a BSC four perspectives; finally, some concluding remarks will be drawn.

56.2 Lean and Green Supply Chain Performance

1. The Lean and Green Supply Chain

There are new opportunities for supply chain management improvement which requires the implementation and application of the business paradigms lean and green. Supply chains need to answer to the market changes and combining these paradigms may be an excellent approach. The deployment of paradigms initiatives on supply chain management influences the performance measurement and change supply chain management in order to obtain a more efficient and sustainable supply chain.

A lean and green supply chain should determine the products to supply, the type of containers to use, and the type of the transport mode to use and the exact information to share, so as to minimize the cost and the lead-time and at the same time reduce the environment impact [6]. Simpson and Power [24] assert that the purpose of lean is to generate a system that is efficient and well organized and applied to the elimination of all waste and a continuous improvement of the system.For these authors [24], the practices that support lean paradigm are related to the practices that support green or environmental performance.

The United States Environmental Protection Agency [26] adds environmental metrics to lean metrics and mentioned that using green environmental metrics in a lean system will allow an organization to record the environmental benefits that are part of lean implementation, as well as identify targets for future improvements. Many organizations that are implementing lean initiatives continually seek to reduce materials, energy, water, space, and equipment reaching environmental improvements [26]. Kainuma and Tawara [13] examined both paradigms extending the range of supply chain to include re-use and recycling throughout the life cycle of products and services. The Shingo Prize award [22]—a lean certification—is based on lean thinking but promotes the protection of the environment, classifying this as an aspect of value and also as a powerful element of continuous improvement [22], considering in their guidelines green performance measures. This can be an indicator that, even lean organizations should be aware to change their structures to become "greener". The synchronization of these two business paradigms becomes an optimal way to achieve a better performance.

2. The Performance Measurement System

The performance measurement systems are important at different levels of decision-making [1]. Measuring, monitoring, and analyzing the progress on a regular basis are the prerequisites for evaluating the performance. According to [22] the performance measurement is what management needs to know to be able to plan, organize, and control. Therefore a performance measurement system is an important tool to give managers the information they need to improve the supply chains [18]. The feedback given by the performance results, through performance measures go to influence the way of work and action programs to be developed in supply chain. In addition [22] mentioned that it should only "measure what matters", reinforced the idea that it is important to define measures that matter to those who will be using them; being essential for continuous improvement and consistent performance [22]. That is, the performance measurements can be better addressed using only a few good measures that represent the important aspects of value [7]. Consequently, it is essential to identify which performance measures really matter to the business, since those measures influence the decisions to be made at different organizational levels [7, 18]. The focus is also on measures that take the supply chain point of view: the financial measures are used on a strategic level instead of non-financial measures that are used on tactical and operational level of an organization [7]. Shingo Prize

[22] mentioned that the performance measurements need to: (1) be directly tied to strategic priorities; (2) be simple and easy to capture; (3) give timely feedback that is tied to the cycle of work; and (4) drive improvement.

Cai et al. [16] mentioned that "since many measurement systems lacked strategy alignment, a balanced approach and systemic thinking, they had difficulty in systematically identifying the most appropriate measures". For these authors to address this difficulty, some researchers have used a well-known performance measurement approach the Balanced Scorecard (BSC) to evaluate supply chain performance. In their work, [15] studied several measurement systems for supply chain performance, but concluded that "the key driving principle, as espoused by the Balanced Scorecard, is that measures should be aligned to strategic objectives".

Since [14] proposed a BSC structure, many organizations have tried to implement it for strategy management. The BSC is a powerful and balanced strategic management system that facilitates the implementation of strategy, using measures to ensure that vision and strategy are implemented and achieved [5]. By the BSC it is possible to examine what is measured and how performance measurement is perceived by entities on supply chain [5]. According to [14], "the balanced scorecard translates mission strategy into objectives and measures organized into four different perspectives: financial, customer, internal business process and learning and growth". Many organizations have its own unique conditions in a way that the BSC framework may be customized [12]. The important is that the main principles of the framework remain the same [12]; it means that measures should be linked across the four perspectives to give information about strategic themes. The set of measures must be part of management system in all levels of the organization and represent a balance between: (1) short-term and long-term objectives; (2) financial and non-financial measures; (3) leading indicators and lagging indicators; and (4) external and internal performance perspectives [12]. The BSC has been recognized as an improved performance measurement system or as a strategic management system [1].

3. The BSC for Evaluation of Lean and Green Supply Chain

Supply chain strategy must be aligned with business objectives [4]. The BSC is developed based on the business strategy. The implementation of the lean and green paradigms starts by being a business strategy. Therefore for the supply chain transformation in a lean and green supply chain must be defined the objectives, measures, targets, and initiatives considered to the BSC framework; each of these must be considered for each identified perspective. Kaplan and Norton [14] refer that the BSC four perspectives should be viewed as a template. For them, depending on the organization strategy one or more perspective can be introduced or in other hand, to use fewer that the four perspectives, measuring the factors that create competitive advantage and innovation for the organization.

Organizations already using the BSC prior to embarking on lean thinking should find the BSC a useful tool for promoting lean [25]. It is important to deploy measures that drive lean behavior by the BSC. For this author, lean management does not require the adoption of a BSC, however, this seems to be compatible with lean thinking. This compatibility is supported by four perspectives: (1) the financial perspective, by delivering value to stakeholders; (2) the customer perspective, supporting lean focus on final customers; (3) the internal business process perspective, which highlights the importance of organizations to adopt a continuous improvement culture; and (4) the innovation and learning perspective, which intends to promote organizational culture changes and respect for people.

In respect to green thinking the authors [14] mentioned that for organizations, environmental clean is a competitive advantage. Therefore green thinking also can be accessed through a BSC framework. Sidiropoulos et al. [23] consider three possibilities to integrate green aspects in BSC: (1) environmental and social metrics can be integrated in the existing four standard perspectives, (2) an additional perspective can be added to take environmental and social aspects into account and (3) a specific environmental and social scorecard can be formulated. In their research, Sidiropoulos et al. [23] developed a BSC with a fifth environmental perspective. These authors defined an Eco-Balanced Scorecard, with respect to a lean and green operations strategy [23]. Hsu and Liu [11] have adopting BSC in environmental strategy management, using a specific environmental BSC.

With these points of view, is possible to assert that BSC with its four perspectives is a good start for developing a performance measurement system that incorporates issues in way to study the lean and green supply chain performance. This can be used as a template to evaluate lean and green supply chain performance. Table 56.1 summarizes the lean and green performance measures classified by the four BSC perspectives and can be considered as a template for a business to evaluate the impact on lean and green supply chain.

56.3 The Lean and Green Balanced Scorecard

The managers in supply chain have the difficult decision to identify the performance measures; managers usually identify the measures according to their objective requirements and practical experiences [16]. Therefore to get a balanced performance measurement they often decide to use the BSC [16]. According to [2] "it is vital that managers stay on the cause-and-effect relationships in strategy when attempting to link measurement with strategy". Shingo Prize [22] mentioned that organizations must follow the linkages to determine the cause-and-effect relationships and how objectives can be achieved. To develop a BSC as a strategic and dynamic performance measurement system, [1] point out three principles: (1) built in cause-and-effect relationships; (2) include sufficient performance drivers; (3) provide a linkage to financial measures. The most of the measures in the supply chain are correlated and have complicated cause-and-effect relationships [16]. These cause-and-effect relationships can make the connections among objectives and measures in the various perspectives.

Hsu and Liu [11] state that "there are strong relations among performance measures covering multiple dimensional but balanced aspects for a delicate strategy control. For example, measures of learning and growth perspective could strongly affect

Table 56.1 List of performance measures identified for lean and green supply chain BSC

Financial	Ref.	Customer	Ref.
Profit after interest and tax	[2, 11, 23]	Customer returns	[2, 10]
Profit from recycle		Responsiveness	[11, 23]
Resource consumption products		On-time delivery	
Gross revenue	[8]	Market share by product group	[2, 12, 23]
Revenue of green products investment	[11]	Quality improvement due to greener products	[11]
Return rate of environment		Green image	
Return on investment	[5, 23]	Product safety	[10]
Disposal costs	[10, 11]	Customer satisfaction index	[2]
Pollution treatment costs	[27]	Service quality	
Return on assets	[8, 13]		
Operational costs	[10, 27]		
Scrap and rework cost	[28]		
Internal business process		Learning and growth	
Process efficiency	[8, 10–12]	Number of accidents	[2, 8]
Operational efficiency		Absenteeism	
Capacity utilization		Labor turnover	
Material waste; hazardous waste	[23, 26, 27]	Quality of professional/technical development	[11]
Water waste; energy waste		Env. education and training	
Scrap/non-product output		Employee's initiative	
Air emissions		Understanding to related policy and laws	
Materials use; water use	[13, 26]	Quality of leadership development	[2]
Energy use		Retention of top employees	
Lead-time	[8]	Rewards and recognition;	[9]
Value added time		Suggestion schemes;	
Non-value added time		Communication between employees	
Perc. of recyclable components	[23]	Information diffusion	[23]
Inventory level	[2, 28]		
Number of certified suppliers	[8, 11]		
Number of suggestions made to suppliers in a year			
Sole sourcing suppliers			
Supplier ability to respond to quality problems	[7]		

internal process perspective and therefore affect financial perspective". Another example is supplied by [1]: "flexibility of service systems to meet particular customer needs (internal business process perspective) will be more likely to meet customer expectations (customer perspective). Higher level of customer expectations will lead companies to supply more innovative products and services (learning and growth perspective). This in turn will increase the market share and profitability (financial perspective)". The cause-and-effect relationship can involve some, the four or more perspectives in the BSC and may evaluate the lean and green supply chain management.

A BSC framework for evaluating lean and green supply chain performance is developed. The four standard perspectives were used where the lean and green measures are selected. These measures were based on literature review (Table 56.1) and they were selected as important features taking into account the following purposes: for financial measures two core measures were selected: (1) "profitability and revenues" which is based on profit after interest and tax, profit from recycle and resource consumption products, revenue and revenue of green products, return rate of environmental investment and return of investment [2, 5, 8, 11, 23]; and, (2) the measure "cost" based on operational costs, disposal and pollution treatment costs [10, 11, 27]; for customer measures were selected the "market share" as market share by product group [2, 12, 23] and "customer satisfaction" that can be measured as customer returns, responsiveness and on-time delivery [2, 10, 11, 23]; for internal business process measures was applied "supplier side management" as the number of certified suppliers, number of suggestions made to suppliers in a year and supplier ability to respond to quality problems [7, 8, 11]; "waste reduction" [5, 27], as it is based on traditional lean wastes and green wastes [26]; and "productivity" was studied based on process and operational efficiency and capacity utilization [8, 10–12]; for learning and growth measures, "employee morale and satisfaction" can be expressed by the number of accidents, absenteeism and labor turnover [2, 8]; "employee's education and training" based on quality of professional/technical development and environmental education and training [11] and "information management" as information diffusion [23].

Related to the "employee morale and satisfaction", Kaplan and Norton [14] considered that "the most satisfied customers were the ones served by the employees who scored highest in morale". Gordon [6] state about the lean and green implementation that employee morale increases through the pride of working for a lean and green organization and report fewer illnesses and accidents. In addition, [26] refers that "when employees take pride in their work there can be a substantial positive effect on organizational morale and that can empower employees and promote an improvement in productivity". Financial benefits may be reached due to improvements in operational efficiency or productivity [19].

According [20], improve productivity and make products with fewer defects to precise customer satisfaction, are some of the goals using lean characteristics as for example continuous improvements and just-in-time philosophy. Gordon [6] states that introducing efficiencies will contribute to earn greater market share. EPA [26] refers that the benefits of coordinating lean and environment pass through cost reduction, improve process flow, meet customer expectations and improve employee morale and commitment.

Employee education and training are main issues waste reduction. The education of employees has a relation with product conformity [11] reducing waste. Besides, it is possible to get financial benefits due to a waste reduction [19]. Learning to see and eliminate waste is the basis of lean initiatives [26]. Thus eliminate wastes and

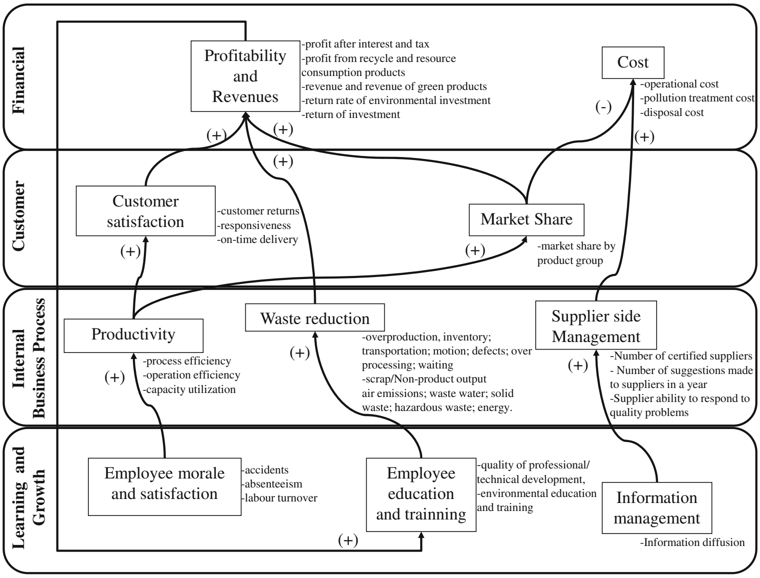

Fig. 56.1 Cause-and-effect BSC perspective

environmental wastes indicate opportunities for saving cost [19, 26]. Another result from lean and green implementation stated by [6] was "paying less for disposal because much less is wasted; earning revenues trough recycling".

A lean and green supply chain requires collaboration with suppliers. According to [24], lean supply chain requires high levels of information sharing, rapid performance improvements with suppliers and minimal transaction costs. The supplier must be convinced that their best interest lies in accepting direction and assistance from their customer [24]. In addition, suppliers that accept to be environmental certificated, knows that additional controls from their customer are often not need [19]; this issue also can be considered a criterion on the supplier selection process [17]. Organizations expect suppliers to get engaged in finding and implementing compatible solutions as lean and green [3]. According to [17] suppliers may incur greater costs while attempting to provide more environmentally responsible or higher quality products.

Based on the described, the cause-and-effect relationships between measures in the four perspectives were defined in Fig. 56.1. With this causal diagram, it is possible to visualize how lean and green measures are related and it is possible to find out an entire sequence of linkages: Increased "employee's education and training" (learning and growth perspective) driving to reduce waste (internal business process perspective), which increased "profitability and revenues" and decrease "cost" (financial perspective). Increased "employee morale and satisfaction", increased "productivity" measure driving improvements in "customer satisfaction" and "market share". These last measures (in customer perspective) increased "profitability and revenues" (in financial perspective), which provides a possibility to make more investment in "employee's education and training" (in learning and growth perspective). Increased "information management" (in learning and growth perspective), may increase "supplier side management" (internal business process perspective) which may cause increases on "cost" (financial perspective).

These linkages in the scorecard are an example of how evaluate the supply chain performance and allow analyze the relationships between the measures.

56.4 Conclusions

This study suggests that BSC can be a management tool for lean and green supply chain performance evaluation and the measures may be correlated in a cause-and-effect relationship. For demonstration purposes, the lean and green performance measures were selected in the four BSC perspectives and based on lean and green implementation it is possible to find an entire sequence of linkages between the perspectives. The BSC is a tool that supports the supply chain improvement, through the performance evaluation determines which initiatives to implement. If organizations take actions by linking the performance measurement system to their lean and green initiatives, then they should be better positioned to succeed in their supply chain management. This work propose a framework considering only the four standard BSC perspectives with the intention to be adapted by all entities in the supply chain in way to capture the performance of the lean and green initiatives along the entire supply chain, in an extended chain.

Nevertheless, some limitations should be noted since the model relationships were established by anecdotal evidences resulting from literature review. For future research, it is suggested another study with others supply chain measures or with another BSC structure. Additionally, to validate and testing the proposed model is suggested the application of a statistical method, the structural equation modeling (SEM). This method has the ability of testing and validity such hypothetical model.

Acknowledgments Authors would like to acknowledge UNIDEMI.

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Chapter 57
Study for Preventive Maintenance Plans and Strategies of High-Value Equipment in Radiation Department of General Hospital Based on Appointment Amount Analysis

Yueyu Li

Abstract How to careful formulate a scientific and reasonable preventive maintenance plan of the hospital's high-value medical equipment is concerned to ensure the normal operation of medical equipment, and reduce the total cost of hospital operation management. The preventive maintenance of equipment has been widely used in traditional manufacturing. In China many General Hospitals also carry on preventive maintenance of medical equipment, but more consider the wear and failure disciplines of medical equipment to formulate preventive maintenance plan, and rarely consider the actual operation of the medical equipment. With the methods of preventive maintenance, this paper counts and analyzes the actual appointment amount of high-value medical equipment in radiology departments of West China Hospital, Sichuan University, and identifies appointment disciplines that governor the use disciplines of medical equipment. According to the use disciplines, the wear and failure disciplines of medical equipment, radiation department can careful formulate scientific and reasonable preventive maintenance plans of medical equipment and strategies. It is important to improve reliability and utilization of high-value medical equipment of radiology departments through the analysis of the appointment amount and combination with the wear and failure disciplines of medical equipment to formulate preventive maintenance plans.

Keywords Hospital high-value equipment · Preventive maintenance plan · Appointment amount analysis · Radiology department

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_57,

57.1 Introduction and Objectives

Many General Hospitals in China have carried on preventive maintenance procedures of medical equipment and ensure the quality and safety as well as prevent failure of medical equipment. How to formulate scientific and rational preventive maintenance plans, and how to reduce the failure for the high-value medical equipment is a problem concerned by hospital management department for the daily operation of General Hospital. In recent years, there are many strategies and methods to formulate preventive maintenance plan of medical equipment. Such as Pandey and Zuo [6] presented the hybrid imperfect repair model under imperfect repair, Naser et al. [5] presented the work order priority method according to the requirements of medical equipment maintenance, Joaquín et al. [2] presented the method according to lack of external service provider's guidance about the preventive maintenance program, related problem and overload equipment. Sitra et al. [7] presented the method according to the need to be repaired and can be repaired, Beatriz et al. [4] presented the method according to the number of treatment, treatment efficiency and hospital administration time directly affected by the medical equipment failure. Ali et al. [1] presented the proactive maintenance method according to comparison. Khalaf et al. [3] presented the method based on greedy algorithm of nonlinear least-squares regression mathematical model for maintenance data of medical equipment. Sharareh et al. [8] presented maintenance/inspection optimization model method according to the classification of different types of medical equipment, and so on.

The West China Hospital of Sichuan University is three A-level General Hospital (hereinafter referred to as General Hospital) of the world's largest single-point scale, national center of severe illness diagnosis and treatment in western China, and the medical level in the national advanced level. In this paper, the research object is its high value medical equipment of the hospital radiology department, included 7 Digital X-ray Radiography (DR) machines, 6 Computer Tomography (CT) machines, 6 Magnetic Resonance Imaging (MR) machines, 2 Gastrointestinal Barium Imaging (RF) machines, which are the world's most advanced medical equipment.

From the view of the analyzing appointment amount of medical equipment, this paper focuses on the research how to carefully formulate preventive maintenance plans and implementation strategies of high value medical equipment in the radiology department, with the aid of the key topic project: Resource Scheduling and Optimization in Medical Services (Fund number: 71131006, 2012.1–2016.12) of National Natural Science Foundation in China.

57.2 Materials and Methods

57.2.1 Basic Strategy and Institution of Medical Equipment Maintenance

As the preventive maintenance strategy of equipment has been widely used in traditional manufacturing in order to avoid excessive maintenance and waste of time and money, a lot of General Hospitals also take the same strategy: the low value (non-important) medical equipment will be repaired after breakdown; the high value (important) medical equipment without failure will be take preventive maintenance actively according to the preventive maintenance plan (or embodiment), by a certain technology and method of preventive maintenance, in order to avoid too long failure time of medical equipment which may greatly influent the daily diagnosis and treatment procedures. According to the size of the maintenance workload and maintenance content for the high value medical equipment, three-level maintenance institution is usually adopted.

1. Daily maintenance: Refers to the medical equipment should be carried on dust removal, cleaning, disinfection, lubrication, tightening loose parts and checking, recording equipment situation, etc. such as the daily maintenance, and commonly by the operators to complete. Generally, (or at least once a week) in 5–10 min after work every day according to the content of the inspection card formulated, the equipment should be check item by item. If found abnormal phenomenon, the equipment should be immediately diagnosed and treated. Practice has proved that about 80 % failures were found early in daily check.
2. Level 1 maintenance: According to the plan or embodiment pre-established with the characteristics and use of medical equipment, generally the medical equipment should be carried on cleaning, lubrication, fastening, and the parts easily failed should be checked, adjusted, and replaced consumable materials. It is commonly completed by operators in guidance with the professional maintenance engineers. Level 1 maintenance generally has a smaller workload, but more times. It can be combined with daily maintenance and inspection.
3. Level 2 maintenance: According to the plan or embodiment pre-established and related technical specifications with the failure frequency, time interval and characteristics of medical equipment, the key parts easily failed should be disassembled, checked, and taken internal cleaning, lubrication, replacement and debugging, as well as the introspection and safety protection, etc. than restored technical parameters and performance indicators like factory's default. It generally is done by professional maintenance engineers. If necessary, it can be finished by manufacturer's technical personnel.
4. Level 3 maintenance: The main part of medical equipment should be checked and adjusted thoroughly, and the wear condition of the main components should be carried on measuring and inspection, generally by professional repair engineer.

57.2.2 Careful Formulate Preventive Maintenance Plan of Medical Equipment

Traditional preventive maintenance plans of medical equipment is typically that equipment management officers predict the situation of medical equipment according to the wear and failure discipline of medical equipment (which is provided by equipment providers), and based on prediction, formulate state detection and maintenance plans of medical equipment with the balance of manpower, spare parts and cost, than choose the optimum solution to organize the implementation, which involves preventive maintenance decisions of medical equipment.

The basic principles of traditional preventive maintenance decisions for medical equipment generally comply with small amount of maintenance, inspection and repair costs, not only to ensure the normal procedures of daily treatment, but also to save maintenance costs. It requires General Hospitals to study on wear and failure disciplines as well as classification of medical equipment to reasonably determine the type and opportunity of maintenance according to the situation of medical equipment, so as to minimize excess maintenance of medical equipment.

It is not easy to formulate a careful and reasonable plan of preventive maintenance for medical equipment with maintenance decisions. Firstly, it has greater blindness in formulating preventive maintenance cycles because of the unpredictability and deviation of wear and failure disciplines for the special medical equipment. Secondly, General Hospitals can not only consider small amount of maintenance and repair costs, and maintenance opportunity determined by the maintenance personnel (department) of medical equipment, but also must make maintenance decisions of medical equipment to take full account of the treatment procedures, the daily operation and management costs of General Hospitals.

From the view of cost, the preventive maintenance cost of medical equipment include not only the direct cost which is bring by the maintenance and repair, but also the loss (opportunity) cost which is bring by the failure of daily treatment procedures because of the preventive maintenance for medical equipment. In this paper, if it carefully formulates scientific and reasonable preventive maintenance plans of medical equipment in accordance with actual operation of medical equipment, the indexes of wear and failure frequency or cycle of medical equipment, the daily treatment procedures of General Hospital should be full considered as the constraints in order to seek the preventive maintenance level of the lowest total cost for medical equipment as the goal.

There already are many related research above that how to determine the wear and failure frequency or cycle. This paper focuses on how to find out the actual daily treatment disciplines of radiology department in West China General Hospital with identifying the patient's treatment appointment disciplines (which usually governor the use disciplines of medical equipment) through analyzing actual treatment appointment amount. And on this basis, with combination of wear and failure disciplines of medical equipment, it can carefully formulate scientific and reasonable preventive maintenance plans and strategies of high-value equipment of radiology department.

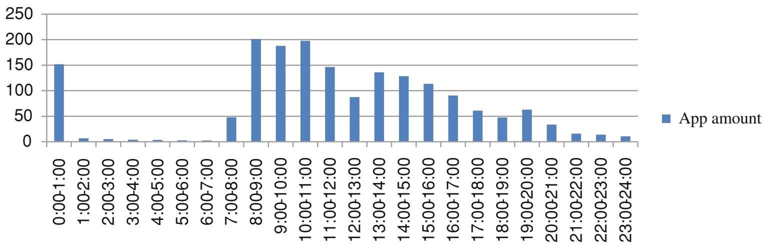

Fig. 57.1 Statistical analysis of diagnosis and treatment appointment (mean) 1 day

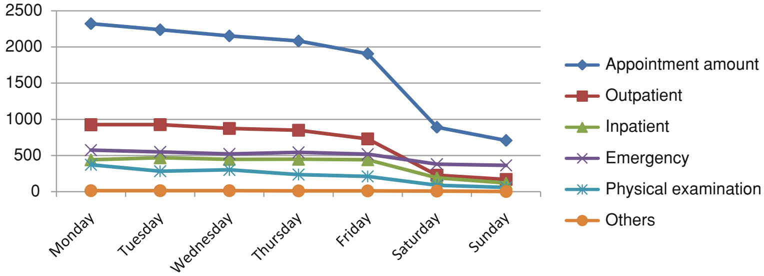

Fig. 57.2 Statistical analysis of diagnosis and treatment appointment (mean) one week

57.2.3 The Appointment Analysis of Radiology Department

This paper collected diagnosis and treatment appointment data (Data Sources: 2011.08–2012.07) of radiology department in West China General Hospital. Analysis is as follows:

1. Statistical analysis of diagnosis and treatment appointment in a day

The Fig. 57.1 shows that, at 8:00–11:00 in the morning is diagnosis and treatment appointment peak one day, in the afternoon, at 13:00–16:00 is another small peak one day.

2. Statistical analysis of diagnosis and treatment appointment 1 week

The Fig. 57.2 of analysis for the various diagnosis and treatment appointments from Monday to Friday shows that the total diagnosis and treatment appointment amount from Monday to Friday is large but on decreasing trend, diagnosis and treatment appointment amount is small from Saturday to Sunday. The diagnosis and treatment appointment amount of outpatient showed a decreasing trend, but that of emergency, inpatient and physical examination is relatively stable.

The Fig. 57.3 shows that total appointment amount is obviously cyclical variation one week, which is more from Monday to Friday, small on weekend, rarely on the case of the big festival and holiday.

3. The statistical analysis of the diagnosis and treatment appointment amount based on medical equipment

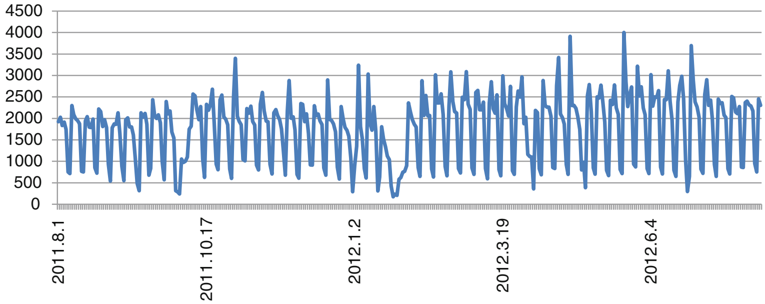

Fig. 57.3 Statistical analysis of the total appointment amount (mean) 1 week

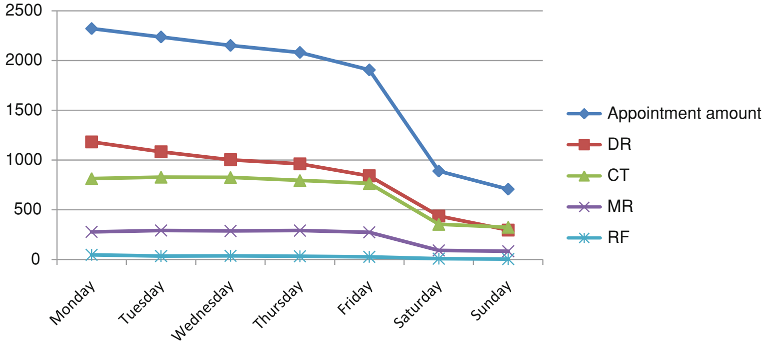

Fig. 57.4 Statistical analysis of the total appointment amount (mean) based on medical equipment 1 week

The Fig. 57.4 of appointment amount for all kinds of medical equipment from Monday to Friday shows that the appointment amount of CT, MR and RF is relatively stable, while DR is high volatility. The appointment amount from Monday to Friday is comparatively large, but shows a decreasing trend. The appointment amount is small in weekend.

The Fig. 57.5 shows that the appointment amount of medical equipment in the radiology department is obviously cyclical variation weekly, more from Monday to Friday, small in weekend, rarely on the case of the big festival and holiday. The periodic variation range of DR appointment amount is the biggest, followed by CT, MR is small, and RF is stable.

57.3 Results

Analytic results show that the patient's appointment amount of radiology department is almost equal to that of medical equipment. The discipline of the appointment amount of medical equipment is basically as the same as the use discipline of

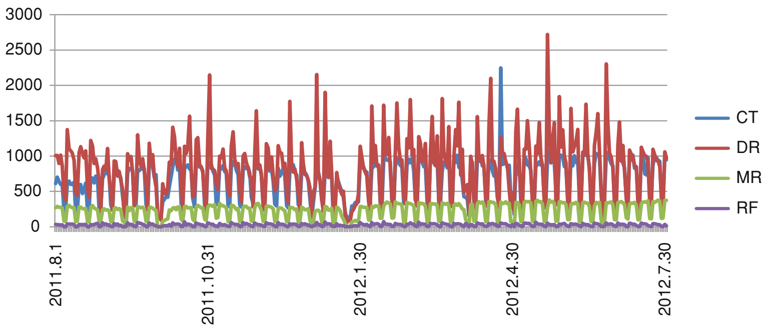

Fig. 57.5 Statistical analysis of the appointment amount based on medical equipment 1 week

medical equipment in radiology department. Therefore, the formulated preventive maintenance plan or embodiment of medical equipment must adequately consider these daily diagnosis and treatment procedure of General Hospitals, such as the use discipline of medical equipment in radiology department, to make sure that the total costs (including the opportunity cost) of maintenance of medical equipment are the lowest. Hence, the strategies of maintenance plan of medical equipment in radiology department as follows:

1. Daily maintenance plan: According to statistical analysis of Fig. 57.1, it is better to execute daily maintenance of medical equipment at 5–10 min before 8:00, or after 23:00. In case of extraordinary situation, it can be also executed between 12:00 and 13:00. According to statistical analysis of Fig. 57.2, it can be chosen Sunday to execute daily maintenance of medical equipment that needs once maintenance every week.
2. Level 1 maintenance plan: According to statistical analysis of Figs. 57.3–57.5, the use discipline of medical equipment regularly changes in a weekly cycle. For smaller workload and more times of level 1 maintenance plan, it can be arranged on Sunday, Saturday or Friday. It is best to be combined with daily maintenance plan. For larger workload and few times of level 1 maintenance plan, it can be arranged on Sunday, Saturday.
3. Level 2 maintenance plan: According to statistical analysis of Figs. 57.3 and 57.5, because the large workload of medical equipment, the level 2 maintenance plan can be arranged on the period during which the appointment amount is small, such as the big holiday with weekends.
4. Level 3 maintenance plan: According to statistical analysis of Figs. 57.3 and 57.5, because it is a large workload and longtime of maintenance to check and adjust the main body of medical equipment thoroughly, the level 3 maintenance plan can be arranged on the period during which the appointment amount is small, such as the national day with an adjacent period.

57.4 Conclusions

The purpose of this paper is seeking the maintenance level to minimize the total cost of medical equipment maintenance and to maximize the guarantee for the actual daily operation of radiology department by analyzing the use discipline of medical equipment and formulating preventive maintenance plan or embodiment of medical equipment within the period the appointment amount is small, as well as combining with the wear and failure characteristics and use situation of medical equipment.

These strategies of formulating maintenance plan of medical equipment not only requires analyzing daily maintenance records which are the occurring time, causes, working hours and break-down time of all medical equipment maintenance and are made analytical tables to analyze, but also statistically analyzing the appointment amount of medical equipment in order to summarize the use discipline of medical equipment and get the time points and periods during which the appointment amount of medical equipment is small as the best time points and periods of maintenance.

Because the Radiology Information System (RIS) of West China Hospital at Sichuan University has been established recently and the data of records is not complete, data sample (Data Sources: 2011.08–2012.07) collected in this paper is not enough large and the statistical analysis of appointment amount and the use discipline of medical equipment needs long time to be verified. Meanwhile, the General Hospital should formulate the corresponding rules and incentive measures to guarantee that the staff of medical equipment department is willing to work on nonstandard work time, weekend and holiday to maintain the medical equipment. However, the method of this paper provides a good exploration and reference to formulate scientific and reasonable maintenance plans of high-value medical equipment at General Hospital.

Acknowledgments This research is supported by the National Natural Science Foundation in China, 2012.1–2016.12 (Grant No. 71131006).

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Chapter 58
Inter-organizational Similarity as a Driver of Knowledge Sharing Within Supply Chains

Xin Gu, Qifeng Wei and Chunlan Yu

Abstract Inter-organizational knowledge sharing is the key research of knowledge management within supply chains. In this study, we empirically investigate the relationship between the similarity of organizations within the supply chain and the efficiency of inter-organizational knowledge sharing. Specifically, the fractal theory is employed to analyze the issues of knowledge sharing, and to both the similar characteristics and efficiency of knowledge sharing, it builds up the evaluation index systems. Moreover, the interview method is adopted to elaborate the partnership among three organizations in the supply chain with a manufacturing firm as the core. Also the corresponding sharing efficiency is analyzed comparatively among them. Empirical results indicate that a positive relation is existed as we predicted.

Keywords Inter-organizational · Similarity · Knowledge sharing · Supply chain · Fractal

58.1 Introduction

The management philosophy of modern corporate has turned from 'vertical integration' to 'horizontal integration', which more emphasizes the process-oriented management, shift from product management to customer management, from inter-enterprise transaction management to relationship management, from material management to information management, from real resources management to virtual resources management, and from simple diversification to management of the core competence. Companies are increasingly focus on their core competitiveness, and start to outsource the non-core businesses. In such case, theorists and practitioners both proposed the concept of 'supply chain competition', namely, the present

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_58,

competition is not still competition among enterprises but the supply chains. In the background of knowledge economy, knowledge management in the supply chain is arousing the attention of scholars at home and abroad, where knowledge sharing and distribution among enterprises becomes the core of research on supply chain knowledge management. Knowledge economy has made the strategic resources of enterprise changing from the traditional financial capital to the knowledge and innovative ability. However, although knowledge sharing is a source for the supply chain to obtain the sustainable competitive advantage, except for TOYOTA and DELL which get succeed by knowledge sharing of supply chains, majority apparently not attain the expected results. So, knowledge sharing only within organization is obviously not enough to meet the requirement of enterprise development, and knowledge sharing between supply chains is generally different from which takes place in the organization. Knowledge management in supply chain gradually becomes the focus of attention of scholars, and knowledge acquisition, sharing, distribution and application are all its content. Further, inter-organizational knowledge sharing is the key of knowledge management within supply chains [1]. However, the supply chain is a dynamic, crossed and complex system, in the face of various stimuli, the reaction of its environmental uncertainty and organizations shows more uncertain, which increases the difficulty of making right decisions of knowledge sharing. Meanwhile, compared with other alliance form, organizations within supply chain have more similarity, which has a vital impact on inter-organizational knowledge sharing activities in supply chain. Some research shows that [2], diversity from knowledge storage, background and other aspects, compatibility from organizational structure and culture, as well as the interaction of inter-organizational relationships, all have impacts on the motivation and mutual trust between organizations, thus affecting the results of knowledge sharing. Nevertheless, does that mean the increasing similarity of organizations within the supply chain promotes the efficiency of inter-organizational knowledge sharing? There's still no conclusion with sufficient evidence yet, which is exactly the question this paper tries to investigate.

58.2 Knowledge Sharing Within Supply Chains

58.2.1 Inter-organizational Knowledge Sharing Process

Now that knowledge sharing is an important part of the knowledge management within supply chains, the efficiency and effect of knowledge sharing will directly affect the effectiveness of knowledge management, but also affect the knowledge application and extent of innovation.

The main purpose of the organizations participate in the supply chain is to achieve the knowledge complementary strengths, and effective knowledge sharing can help to fully learn or utilize the knowledge resources outside the organization, see Fig. 58.1. Knowledge sharing among organizations in supply chain means that,

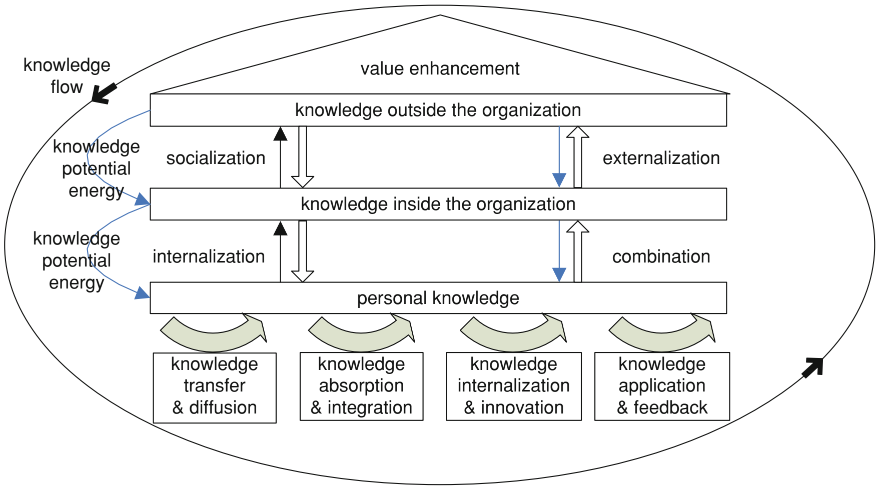

Fig. 58.1 Logical process of inter-organizational knowledge sharing

various organizations transfer and exchange the explicit and tacit knowledge in the supply chain platform, and realize the mutual transformation and integration, to produce synergetic value, thereby increase the innovative and adaptive ability of knowledge agent. Seeing from the structural characteristics of the supply chain, activities of knowledge sharing among organizations in supply chain seem more complex than that inside single organization, and also different from that in other alliance organizations. With respect to be inside the organization, inter-organizational knowledge sharing within supply chain is characterized by the network form of cross-organizational boundaries, with characteristics of complex, dynamic and overlap.

58.2.2 Similarity Analysis Within Supply Chains

Organizational knowledge search and absorb is based on a certain knowledge stock, during the learning process, people always generate their interest in new knowledge within the scope of their knowledge and ability, and the learning speed of knowledge associated with its knowledge base is much faster than those out of the range. Therefore, cooperation between organizations in the supply chain is based on a certain overlapping of knowledge level and knowledge structure, and generates knowledge sharing behaviors on the demand for complementary knowledge.

The supply chain could be seen as a ‘big business’, inter-organizational communication, coordination, commitment and other activities are carried out under such circumstances, which enhance the strength of the relationship between organizations and improve the level of mutual trust, and then make the information exchange between organizations more accurate and understanding, reduce the opportunistic behavior and conflict in the process of cooperation, form a share culture more recognized, which is conducive to the spread and sharing of tacit knowledge in supply chains. In the developing process of supply chain, there is a same or similar organizational culture and institutional environment among the organizations, the economic behaviors of organizations are deeply embedded or rooted in a common language circle with same background knowledge and trading rules, which will make tacit knowledge in supply chains difficult for those external organizations to get acquired, but inside the supply chain, it is known to all of the organizations, which is actually making the inter-organizational knowledge sharing within the supply chain more favorable. For the effective knowledge sharing, there is a certain similarity of knowledge sharing culture, learning ability and organizational structure among nodal enterprises within supply chain, such as a relatively sound knowledge management system, a certain stock of knowledge, perfect information infrastructure, a high degree of knowledge coding, high-quality staff capacity, and consistency of culture and business philosophy. If the organizational knowledge sharing capability is too bad, that will not only reduce the efficiency of knowledge sharing, but greatly affect the enthusiasm of sharing knowledge of other nodal organizations.

58.3 Methods

58.3.1 Fractal Supply Chain

As can be seen from the structural model of the supply chain, it is such a demand model composed of supply network formed by all levels of suppliers, and a sales network formed by all levels of distributors, retailers and customers. The difference with other organizations lies on its network chain relationship which attaches importance to the core organization, the degree of trust and cooperation among organizations is relatively high. In the construction and operation of the supply chain, core organizations are maintaining their competitive advantage by continuously selecting the optimal partner, or even forming business relationships with other core organizations in the supply chain and competitors. Seen from the overlapping nature, complexity, dynamics and other characteristics of supply chains, there may be some secondary core organizations in the supply chain, these organizations will constitute their own supply chains, or cooperate with other nodal organizations in the supply chain, forming a complex relationship between supply and demand, to present a nested integration structure. In addition, the overall common objective and sincere cooperation among organizations within the supply chain has a significant impact on the structural stability of the supply chain, therefore, a long-term mutually beneficial cooperation relationship should be formed, to develop into a stable and cooperative relation. This partnership is formed by a large amount of information transmission, which means various nodes cooperate together from the transmission of information on a certain commonality or similarity. According to the fractal theory, we

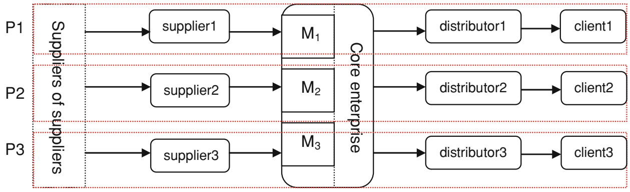

Fig. 58.2 Fractal supply chain structure

consider the supply chain system as a fractal unit, which is composed by various nodal organizations. Each unit has its own objective, namely to maximize the profit, and their behaviors should be restricted by the rules of cooperative law between nodal organizations, the resources are limited by the supply capacity of upstream suppliers and their financial, and operating conditions as well. Which apparently meets the three-dimensional space of fractal unit stated by Hartmann and Borgmarm [3], namely, goals, constraints and resources. The main similarity is determined based on the overall goals of the supply chain and sub-goals of fractal units. For example, the fractal supply chain could be established according to the product or service module, hierarchy of organizations, or market areas. But no matter what kind of criteria established by, that should be adapted to the target of supply chain. The fractal supply chain established by product module is composed by suppliers, manufacturers and vendors, and the entire supply chain is actually constituted by many sub-supply chains as supply, manufacture and marketing, which shows a 'holographic' property [4]. Where P1, P2, P3, respectively, means three fractal supply chains, suppliers, manufacturers, distributors, customers are fractal elements in them (Fig. 58.2). In essence, whether it is the core organization in the supply chain, or other nodal organization, it's a fractal element, which has the self-similar, self-control, self-optimization features, only differs in each level. Different levels of the fractal supply chain element are supporting the process of knowledge sharing throughout the supply chain. Knowledge sharing among organizations within the supply chain constitutes a cross-system of knowledge-sharing, and its knowledge sharing has similarity too. Therefore, knowledge sharing system within supply chains has fractal characteristics, and we can use the fractal theory to further discuss the issue of evaluation on inter-organizational knowledge sharing within supply chains.

Based on fractal theory, the paper analyzes the similar characteristics of some nodal organizations with the perspective of fractal supply chain. In a supply chain, there is a certain knowledge potential, and a certain need for knowledge sharing, yet there are some differences in organizational culture, information infrastructure, organizational structure, stock and structure of knowledge, in this case, to evaluate the similarity between relevant organizations of various factors, and to prejudge the effectiveness of inter-organizational knowledge sharing, is beneficial to weigh both the costs that knowledge sharing activities have to pay and earnings.

58.3.2 Evaluation of Inter-organizational Knowledge Sharing in Supply Chains Based on Similarity

58.3.2.1 Evaluation Index System

In order to compare the effects of knowledge sharing among nodal organizations within the supply chain, the paper analyzes the similarity characteristics among organizations in the supply chain from five dimensions: support capability for knowledge sharing platform, knowledge level, structure and institution, organizational compatibility and the learning ability.

Specifically, the evaluation index system is established as follows, see Table 58.1. But, this paper just chooses some quantitative indexes therein for use in consideration of complexity, although we have also used all indexes for operation, which shows a similar result.

58.3.2.2 Evaluation Model

Considering these two fractal supply chain units A and B, $\{X_i\}_i^n$ means the degree of self-similarity of fractal supply chain unit. n is the target amount, $i = 1, 2, \cdots, l$ is the quantitative index, $i = (1 + 1), \cdots, n$ is the expert evaluation index, namely the qualitative index, yet, we only use these quantitative indexes for calculation in the paper. Different fractal supply chain unit has its corresponding value, we define the specific value of evaluation results of A and B these two fractal units of the supply chain as a result of quantitative index, expresses as $r_j = a_j/b_j$, and a_j and b_j, respectively, are quantifiable indexes of evaluation on their fractal supply chain units. The evaluation result of for the kth expert to the $n - 1$th evaluative index is expressed as a percentage, marked as r_{ij}, which means the evaluation of the ith expert on the jth similarity index of A and B two fractal supply chain units. The qualitative evaluation matrix is listed as follows:

$$V = \begin{bmatrix} r_{1,1} & \cdots & r_{1,j} & \cdots & r_{1,n-1} \\ r_{2,1} & \cdots & r_{2,j} & \cdots & r_{2,n-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ r_{k,1} & \cdots & r_{k,j} & \cdots & r_{k,n-1} \end{bmatrix}, \quad i = 1, 2, \cdots, k, \;\; j = 1, 2, \cdots, (n-1). \quad (58.1)$$

Assuming that the weights of evaluation from k experts for $n - 1$ indexes make no different, then, $r_j = \frac{\sum_{i=1}^{n} r_{ij}}{k}$. Considering synthetically both the qualitative and quantitative indexes, we get the similarity matrix function by data normalization:

$$Z_j(A, B) = \begin{cases} a_j/b_j, & j = 1, 2, \cdots, i \\ r_j/100, & j = (i+1), \cdots, n. \end{cases} \quad (58.2)$$

To the evaluation result Z_j, $j = 1, 2, 3, \cdots, n$, construct an N-dimensional space, Z_j is the coordinate of that N-dimensional space, and d_j is defined as the Euclidean

Table 58.1 Overall evaluation index system

	First-grade index	Second-grade index
x_1	Informationization degree	• Percentage of employees with computers
		• Computer networking rate
		• KMS application coverage
		• Proportion of knowledge sharing platform input
	Technology application level	• Construction and use of the database
		• Motivation of organizations involving in building knowledge-sharing platform
		• Construction level of knowledge portal
	System compatibility	• Compatibility with other organizational information systems
x_2	Knowledge within the organization	• Talent turnover
		• Talent wastage rate
		• Bachelor degree or above
		• R&D personnel proportion
		• Average education training costs
		• Opportunity of average individual education training
	Knowledge outside the organization	• Customers satisfaction
		• Customers loyalty
x_3	Organizational structure	• Knowledge management structures
		• Degree of flattening of the organization structure
	Organizational Institutions	• Liberal exchange of knowledge
		• Innovation failure tolerance
x_4	Organizational culture consistency	• Emphasis on knowledge management
		• Establishment and implementation of knowledge-sharing exchange mechanism
		• Establishment and implementation of knowledge-sharing exchange mechanism
		• Establishment and implementation of Innovation failure tolerance mechanism
	Organizational culture openness	• Degree of freedom of expression in the organization
		• Degree of mutual questioning in the organization
	Mutual trust of organizations	• Degree of compliance with contract
		• Degree of trust on original contract and other information
		• Willingness to risk-sharing and cost-sharing
x_5	Willingness to learn	• Frequency of active communication, exchanges, mutual learning within the organization
		• Consciousness of applying new knowledge to implement daily works
		• Degree of rejection on implementation of new work, new system or new technology
	Absorptive capacity	• Ability of identifying changes that external new knowledge to the organization
		• Ability of integration of new knowledge with other knowledge
		• Construction and utilization level of knowledge map
	Integrating capacity	• Arranging knowledge inside and outside the organization
		• Building of experience case databases
		• Classification and standardization of knowledge

distance from various points to the origin, all of these points are grouping together to constitute a subset of N-dimensional space, then we can use relations-measuring method to find the fractal dimension [5]. Centered at the origin, arbitrary radius r, $r \in [\gamma]$, $\gamma = \max d_j$, $j = 1, 2, 3, \cdots, n$, the proportion of numbers of Z_j, marked $N(r)$, contained in the ball in N points is $M(r) = \sum_j^n H(r - Z_j)$, $H(x)$ is the Hevaiside function, that is

$$H(x) = \begin{cases} 1, & x > 0 \\ 0, & x \leq 0. \end{cases} \quad (58.3)$$

Obviously, $M(r)$ is a an increasing value, and $\lim_{r \to 0} M(r) = 0$, $\lim_{r \to \gamma} M(r) = N$. Thus when $r \in (0, \gamma)$, the change of $M(r)$ with γ shows some power-law distribution, namely, $M(r) \propto \gamma^D$, the set has fractal characteristics, the fractal dimension is $D = \frac{\ln M(r)}{\ln r}$, in the bilogarithmic graph of $\ln M(r) - \ln r$, we could use linear regression to fit the straight slope of region, and to calculate the fractal dimension D, which depicts the similarity among supply chain units, the smaller the fractal dimension, the less the similarity; Conversely, the bigger the fractal dimension, the more the similarity.

58.3.2.3 Efficiency Evaluation of Knowledge Sharing Between Fractal Units

To further explain the similarity of characteristics of knowledge sharing between different supply chain organizations corresponding to the different effects of knowledge sharing, this paper calculates the actual efficiency of knowledge sharing between different organizations after surveying in order to confirm the contents of the study above. The evaluation system of knowledge sharing between organizations is a complex system, so, only in accordance with a certain kind of rational way, can we choose the key indexes to do data processing, form a rational evaluation system, in order to make a comprehensive assessment on the efficiency of inter-organizational knowledge sharing within supply chains, in a comprehensive cost of the reasonable range.

Based on the above considerations, both with the research reference from Hu [6] and Hamel [7], the paper uses expert interviews to evaluate the effect of knowledge sharing, specific indexes include: Satisfaction on cooperative members, Customer's Reaction on the cooperation, Market share of innovative products, Profit rate of innovative products, Use of BBS, Learning competence. The index system for efficiency of knowledge sharing is shown in Table 58.2. In summary, the logical process of evaluation on efficiency of knowledge sharing on the basis of the similarity between fractal units is: first, at the beginning of knowledge sharing, due to various reasons, there is some knowledge potential existed between fractal units, which would adversely affect the efficiency of knowledge sharing objectively. Second, in the knowledge sharing process, fractal culture, structure, institutions and other knowledge-sharing environment will generate objective impact on knowledge sharing efficiency. Third, for the above objective existence of these effects, the only way to improve the organizational

Table 58.2 Index system for efficiency of knowledge sharing

Sharing efficiency	Satisfaction on cooperative members
	Customer's reaction on the cooperation
	Market share of innovative products
	Profit rate of innovative products
	Use of BBS learning competence

Table 58.3 Index system for efficiency of knowledge sharing

Index	a_j	b_j	c_j	$Z(A, B)$	$Z(A, C)$	$Z(B, C)$
Percentage of employees with computers	0.75	0.71	0.72	1.06	1.04	0.99
Computer networking rate	0.73	0.69	0.71	1.09	1.20	1.10
KMS application coverage	0.78	0.81	0.76	1.45	1.07	0.73
Proportion of knowledge sharing platform input	0.35	0.33	0.37	1.00	1.33	1.33
Talent turnover	0.33	0.32	0.28	1.02	1.15	1.12
Talent wastage rate	0.06	0.05	0.04	1.03	1.18	1.14
Bachelor degree or above	0.48	0.44	0.40	1.20	1.50	1.25
R&D personnel proportion	0.16	0.11	0.15	1.17	0.78	0.67
Opportunity of average individual education training	2	2	1.5	1.09	1.06	0.97
Average education training costs	860	840	750	1.06	0.95	0.89

learning ability and the knowledge sharing efficiency is continuous exchanges and cooperation. Fourth, the relation between five parts including support capability for knowledge sharing platform, knowledge level, structure and institution, organizational compatibility and the learning ability, and the knowledge sharing efficiency shows a causation, that is, the five aspects can determine the efficiency of knowledge sharing, the result to some extent is a response to the similarity evaluation results.

58.4 Results

In order to analyze the effect of inter-organizational knowledge sharing within supply chains, study the process of knowledge sharing in inter-organizational units based on the supply chain, and to illustrate the calculation given above, the interview method is adopted to describe the partnerships of supply chain with more than three organizations with the manufacturing company as the core, and respectively, compare those five aspects. Assuming there are three organizations A, B, C, whose index can be expressed by a_j, b_j, c_j. After the analysis on the quantitative indexes, we get the calculated results and Z_{ij} reported as follows (Table 58.3).

Make a double logarithmic regression of $\ln M(r) - \ln r$ to have a similarity evaluation on the table above, we get the results are depicted as follows (Fig. 58.3).

Compare the knowledge sharing efficiency of three fractal units, the results are shown as follows (Tables 58.4, 58.5, 58.6).

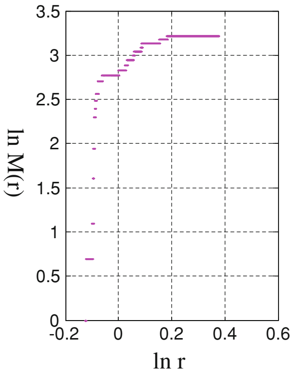

Fig. 58.3 Fractal supply chain structure

Table 58.4 Processing data of unit A and C

Decision members	Satisfaction on cooperative members	0.91
	Customer's reaction on the cooperation	0.83
	Market share of innovative products	0.21
	Profit rate of innovative products	0.67
	Use of BBS	0.80
	Learning competence	0.79

Table 58.5 Processing data of unit B and C

Decision members	Satisfaction on cooperative members	0.84
	Customer's reaction on the cooperation	0.82
	Market share of innovative products	0.17
	Profit rate of innovative products	0.67
	Use of BBS	0.78
	Learning competence	0.72

Table 58.6 Processing data of unit A and B

Decision members	Satisfaction on cooperative members	0.86
	Customer's reaction on the cooperation	0.82
	Market share of innovative products	0.20
	Profit rate of innovative products	0.68
	Use of BBS	0.78
	Learning competence	0.75

58.5 Discussion and Conclusion

There are many ways to determine the fractal dimension, and this paper uses round cover method, which is often used in a fault area. Use circles with different radiuses $(r_i, i = 1, 2, \cdots, n)$ to cover the fault zones. The relation between length of fault area

$L(r_i)$ and the radius (r_i) is: in $L(r_i) = 2r_i * N(r_i)$, $N(r_i)$ refers to the amount of circles with the radius (r_i) covering the fault zones. If mark r_i and $L(r_i)$ $(r_i, i = 1, 2, \cdots, n)$ in the bilogarithmic graph of $\ln M(r) - \ln r$, we can get a straight line with a slope b, its sub-dimension is $D = 1 - b$. Based on the fitting result, $D(A, B)$ is 23.04, $D(A, C)$ is 26.01, $D(B, C)$ is 21.61, fractal supply chain unit with the biggest degree of similarity is A and C, and then A and B, B and C the smallest. That tells the organizational structure and culture between fractal supply chain unit A and C are more similar.

Moreover, make a double logarithmic regression of $\ln M(r) - \ln r$ to the Tables 58.4, 58.5, 58.6, we get the results: 24.6, 18.3, 20.1. Obviously, the degree of similarity between organization A and C is the biggest, and its corresponding efficiency of knowledge sharing is exactly the highest, relatively, the degree of similarity between organizations A and B, B and C is smaller, so its efficiency of knowledge sharing shows a low level. Thus, it is rational to infer a certain level of knowledge sharing by studying the similarity between the supply chain organizations, the evaluation system designed has some practical value, which offers a new idea for research of knowledge sharing between organizations within supply chains.

Based on the above analysis, the supply chain is dynamic and complex, each nodal organization has different characteristics due to the aspects of its structure, culture, values, strategic objectives, technical specifications, etc, which results in a difficulty in organization coordinating, hinder the smooth conduct of knowledge sharing, inter-organization knowledge sharing seem much more complex than the knowledge sharing within the organization. Similarity of technical specifications, organizational culture, sharing mechanism and some other aspects between the organizations greatly affects the effectiveness and efficiency of knowledge sharing, the more similar these aspects, exchanges and cooperation between organizations will be more successful, and the coordinated management will be easier too. With a certain knowledge potential, the higher the degree of similarity between the organizations in all aspects, indicating that more knowledge resources can be shared or transferred between the organizations and the organization operation shows more coordinated; higher degree of cultural integration between organizations, the higher the efficiency of knowledge sharing. Complementary effects from knowledge activities between different organizations of individuals, teams, departments, supply chains will be more likely to occur. The similar characteristics organizations within supply chains have, dramatically not promote the efficiency of knowledge sharing within supply chains, but on the other hand removes the barriers of inter-organizational knowledge flows, thereby improve the organizational decision-making ability and creativity, and ultimately form the competitive advantage for sustainable development. According to the fitting results, similarity degree between organizations A and C is higher, so the barrier of knowledge flows shows smaller, and they have better effectiveness of knowledge sharing, and it is easier to for them to gain a competitive advantage, thereby to enhance the overall advantage of the supply chain.

Acknowledgments This work is supported by the Sichuan University's Special Research Program for the Philosophy Social Science from the Subordinate Universities of Ministry of Education's

Basic Research Foundation (SKX201004) and Innovation Team Project of Education Department of Sichuan Province 'Knowledge Chain Management' (13TD0040).

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Chapter 59
Study of Trade Credit Strategies and Conditions in Supply Chain Based on Perfectly Competitive Suppliers

Jinjiang Yan, Hong Cheng and Xianyu Wang

Abstract Considering uncertain market demand, this paper focuses on strategies and conditions of trade credit from the perfectly competitive supplier to the retailer. With game theory and financial, the analysis shows that the retailer's wholesale price is higher than the unit cost. But the retailer's order quantity has not been distorted. The analysis also shows that the supplier supplies trade credit as the retailer's will under some condition. But he will limit retailer's order quantity under some other condition. This study explains the economic phenomena that the supplier will limit the order quantity for some retailer. Some advices about trade credit in supply chain are given to the management decision maker.

Keywords Uncertain demand · Perfectly competition · Trade credit strategy · Trade credit condition

59.1 Introduction

Capital shortage is not only the bottlenecks of small and medium-sized enterprises' development but also the limitation of large enterprises' expansion. Trade credit, as an important financing way for solving capital shortage, is widely used in the world. Some literatures showed that the trade credit could takes place of the loan from the third financial institutions under certain conditions [6, 8]. Trade credit plays an important part in China's economic development. State-controlled firms in China receive preferential treatment when borrowing from commercial banks, and

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_59,

in contrast, private controlled firms rely on informal finance and trade credit which is from suppliers and extended to customers [17]. Trade credit theory should be developed to direct the practice.

Under the stable market demand or demand rate, after Goyal [4] introduced the economic order quantity model (EOQ) to trade credit, many subsequent researchers expanded the model. Nowadays, the main focuses of trade credit study are supplier's trade credit policy and expansion under different situation in supply chain. For example, Lou and Wang [9] proposed an economic order quantity mode from the vendor's view. They wanted to help the vendor determine its optimal trade credit policy. The optimal trade credit policy is the conditional trade credit not the unconditional trade credit under a supplier-Stackelberg setting [21]. Uthayakumar and Priyan [15] studied the integrated production-distribution inventory model by considering the trade credit period from the vendor to the buyer. Wang [16] developed an economic order quantity mode for the vendor with consideration that the deteriorating products had their maximum lifetime. Chung [3] studied a new inventory model by considering two levels of trade credit to relax the basic assumptions of the traditional economic production quantity model to improve the environment of the use of it. It is clear that the study under certain demand progress very quickly and the achievement is abundant.

The market demand cannot be forecasted accurately, especially for the alone firm. So, the retailer has inventory risk under uncertain demand. It will bring out default risk to the supplier on account of trade credit [8]. So, trade credit should be controlled and managed properly to make it develop sanely. Considering the supplier's default risk, some literatures focused on the risk assessment [18] and some more focused on the credit contract to control the risk. Under fuzzy demand, Hu and Yan [5] set up bi-level decisions models by adopting the negative exponential discount to study the retailer's optimal ordering strategy and optimal pricing strategy under the situation that the retailer had capital constraint. Facing random demand, Zhang and Luo [20] discussed the optimal credit period using auction theory by considering that both players had private information about their capital time cost. Yu and Huang [19] studied the supply chain coordination using revenue-sharing contract. But, all of them just considered the retailer's risk from uncertain demand and ignored the supplier's default risk because of trade credit. For example, the supplier will lose the credit payment if the retailer has not enough money to pay it.

Considering both the retailer's inventory risk and the supplier's default risk, some literatures studied how to make the retailer decide his ordering quantity as the supply chain's angle by use of buy back contract [7, 8]. The retailer could borrow from bank or ask for trade credit from supplier to solve his capital shortage. Ren and Chen [12] studied the retailer's ordering strategy and the supplier's interest rate policy using Stackelberg game. The supplier was dominant. Results showed that the supplier had attained all profit of the supply chain. Chen [1] proved there were equilibrium solutions consisting of retailer's order and the supplier's wholesale price in the frame of Stackelberg game. These literatures have important significance for the supply chain leaded by the supplier.

Nowadays, retailer's position is more and more important in the supply chain. In some supply chain, the retailer is dominant. The seller's market is changing to the buyer's market. The competition among suppliers is more and more intense. So, there are some study focusing on the supply chain consisted of one retailer and some competitive suppliers. Mishra [11] studied the inventory management and brand management by considering the supply chain consisted of one retailer and two suppliers. Su and Liu [13] studied the negotiation strategy between a single retailer and some competitive supplier. In practices, middle and small supplier compete intensely to supply the big mall. They are forced to supply trade credit. But they only get little profit because of the perfectly competition supplier market. Under this situation, there are some literatures studying from the retailer's standpoint. For example, Teng et al. [14] studied the optimal trade credit period and order quantity from the retailer's view, by considering that production cost declined and obeyed a learning curve phenomenon. The two-echelon trade credit is studied too. Luo and Shang [10] studied the retailer's optimal inventory policy by considering that the firm provided trade credit to its customer while receiving it from its supplier.

All study bases on the assumption. The trade credit will be adopted by the retailer and supplier. And the credit amount the retailer asks will be satisfied. But in practices, there are some limits in the credit amount. The credit amount depends on the retailer's own capital. The retailer with large capital can obtain the credit amount he asks. The retailer with little capital will get little credit amount. Cheng and Wang [2] tried to explain credit limit. But it is more like equity financing not the credit financing.

So, there is a blank in the credit limit and credit condition study, especially under the situation that the retailer is dominant. This article focuses on the supplier's wholesale price strategy and the retailer's ordering strategy to find out the condition of trade credit implementation. The supplier has default risk because of trade credit and uncertain demand. It is considered that the supplier is in a competitive market. This means the retailer will be the dominant in supply chain. This paper will not only develop the credit contract theory, but also has certain significance for guiding the trade credit practices.

This paper is organized as follows. Section 59.2 introduces the notations and model assumptions. Section 59.3 gives the basic model. Section 59.4 analyzes the supplier's wholesale strategy. Section 59.5 solves the retailer's order strategy. Section 59.6 analyzes the condition of trade credit implementation. Section 59.7 concludes this paper.

59.2 Notations and Assumptions

Notations and assumptions used in this paper are giving as following.

1. Random market demand q varies in $[0, b]$. Its distribution function is $F(q)$ which is continuously differentiable. Its density function is $f(q)$. The retailer and the supplier have the same expectation on the market demand q.

2. The supplier's cost is c per unit product. He decides the wholesale price w. The retailer's order quantity is Q and it will be provided. The retail price p is constant and this is proper if the market is competitive or limited price. At the end of the sale period, the salvage value is $S(S < c < p)$ per unit.
3. When the retailer's money η cannot pay off the payment $wQ(\eta < wQ)$, the trade credit will be adopted. The retailer pays η when he gets goods. The remaining payment $(wQ - \eta)$ will be paid at the end of the sale period. The retailer cannot order again during the period of sale.
4. The retailer's liability is limited. If the products are sold out, the retailer will pay off the debt. If products aren't sold out, the retailer will pay all his money for the debt. It means he must pay the sum of the sale revenue pq and the salvage value of unsold products $S(Q-q)$. Then he files for bankruptcy. Because the retailer's liability is limited, the supplier cannot recover his all money.
5. The supplier market is perfectly competitive.
6. To simple the computation and focus on the credit risk, it is assumed that the opportunity cost rate is θ in a whole sale period. Both the supplier and the retailer are risk neutral.

59.3 The Model

The supplier has default risk because of trade credit and uncertain demand. He can get back the debt only if the debt isn't high than the sum of retailer's sale revenue and the salvage value of unsold products. It means that the retailer can pay off the debt $(wQ - \eta)$ when $q \geq Q_0(Q_0 = \frac{wQ-\eta-SQ}{p-S})$. When $q < Q_0$, the retailer cannot pay off the debt. He could only pay back $pq + S(Q - q)$ and file for bankruptcy. So, the expected profit functions of the supplier and the retailer are as following respectively:

$$\pi_s = \eta + E[\min[pq + S(Q - q), wQ - \eta] - (cQ - \eta)\theta - cQ, \tag{59.1}$$

$$\pi_r = E[\max[0, p\min[q, Q] + S\max(0, Q - q) - (wQ - \eta)]] - \eta(1 + \theta). \tag{59.2}$$

Suppose the supplier market is perfectly competitive. The retailer is dominant in supply chain and he will choose the order quantity to maximize his profit. The supplier asks a competitive wholesale price. The converse-solving method is used to solve this problem.

59.4 The Supplier's Wholesale Strategy

The perfectly competitive supplier only gets the reserved profit. To simplify the computation but not lose the generalization, it is supposed that the reserved profit is zero. So, the wholesale price w^* is determined by the following equation.

$$E[\min[pq + S(Q-q), wQ-\eta]] - (cQ-\eta)(1+\theta). \tag{59.3}$$

Conclusion 1: There is a solution of $w^* \in [c, +\infty]$ which satisfies Eq. (59.3) if and only if the condition $E(pq + S(Q-q)) \geq (cQ-\eta)(1+\theta)$ can be satisfied.

The formal proof of this conclusion can be found in appendix.

According to Eq. (59.3), we can obtain the supplier's wholesale as following:

$$w^* = \frac{\int_0^{Q_0}(p-S)F(q)dq + (cQ-\eta)\theta}{Q} + c. \tag{59.4}$$

It is obvious that $\int_0^{Q_0}(p-S)F(q)dq + (cQ-\eta)\theta$ is positive. So, the inequation $w^* > c$ can be got.

The first derivatives of Eq. (59.3), with respect to η, θ, c and S respectively, are as following:

$$\frac{\partial w^*}{\partial \eta} = -\frac{F(Q_0)+\theta}{Q\bar{F}(Q_0)} < 0, \tag{59.5}$$

$$\frac{\partial w^*}{\partial \theta} = \frac{cQ-\eta}{Q\bar{F}(Q_0)} > 0, \tag{59.6}$$

$$\frac{\partial w^*}{\partial c} = \frac{1+\theta}{\bar{F}(Q_0)} > 0, \tag{59.7}$$

$$\frac{\partial w^*}{\partial S} = \frac{Q_0F(Q_0) - QF(Q_0) - \int_0^{Q_0}F(q)dq}{Q\bar{F}(Q_0)} < 0. \tag{59.8}$$

It should be noticed that there is $0 \leq Q_0 < Q (0 \leq \frac{wQ-\eta-SQ}{p-S} < Q)$.

So, according to Eqs. (59.5)–(59.8), parameters' effects on the wholesale price are clear. Retailer's own capital η and the unit salvage value S have negative effect on it. But the opportunity cost rate θ and the unit cost c have positive effects on the wholesale price.

Conclusion 2: In the trade credit, the perfectly competitive supplier asks the wholesale price w^* which is higher than the unit cost. It will decrease when the retailer's own capital or the salvage value increases. It will increase when the opportunity cost rate or the supplier's unit cost increases.

This conclusion shows that, to make sure the profit non-negative, the suppliers must adjust the wholesale price, considering the products' salvage value at the end of the sale period, the retailer's own capital, the opportunity cost rate and the cost per unit. To get the low wholesale price the retailer should enlarge his own capital amount and choose to sale the products which have a high store of value at the end of sale period. So, the retailer should choose the industry to enter in cautiously.

Table 59.1 Effect on the w^* and Q^* from parameters

	η	θ	S	c
w^*	$-$	$+$	$-$	$+$
Q^*		$-$	$+$	$-$

59.5 The Retailer's Order Strategy

The supplier asks the wholesale price w^* according to Eq. (59.4). The retailer chooses his order quantity Q according to his own capital and the wholesale price. Then, Eq. (59.2) can be simplified as following by Eq. (59.3).

$$\pi_r = pQ - \int_0^Q (p - S)F(q)dq - cQ(1 + \theta). \tag{59.9}$$

By equating the first derivative of Eq. (59.9), with respect to Q, to zero at $Q = Q^*$, we obtain the retailer's optimal order quantity and it is

$$Q^* = F^{-1}\left(\frac{p - c(1 + \theta)}{p - S}\right).$$

The supplier's unit cost and opportunity cost rate have negative affection on the order quantity. It is affected positively by the salvage value. But it isn't affected by the retailer's own capital. These relationships and that in the part above can be given in Table 59.1 to make it clear. The "$-$" means negative effect and the "$+$" means positive effect. The blank space mean there is no direct effect. In the integrated supply chain, the expected profit of the whole chain is $\pi = p\min[Q, q] + S\max[0, Q - q] - cQ(1 + \theta)$ at the end of the sale period. By its first order condition, the optimal order quantity of the chain is

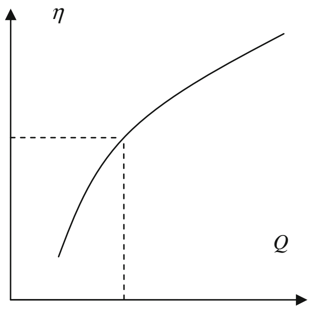
$$Q_c = F^{-1}\left(\frac{p - c(1 + \theta)}{p - S}\right).$$

It is easy to find that Eq. (59.9) is the same as the whole chain's profit and the retailer's order quantity Q^* is equal to the chain's order quantity Q_c. So, we can conclude that the retailer gets all profit of the supply chain and his order quantity has not been distorted.

Conclusion 3: The retailer's own capital doesn't affect the order quantity which is equal to the integrated supply chain's. And the retailer gets all profit of the supply chain.

According this conclusion, trade credit will not change the fact that the retailer will get all profit of the supply chain if the supplier is in a perfectly competitive market.

Fig. 59.1 The supplier's equal profit curve



59.6 The Condition of Trade Credit Implementation

The retailer's order quantity has nothing to do with his own capital if the supplier prefers to the trade credit. The supplier will prefer to the trade credit only if he can get non-negative profit from it. According to above conclusions, the perfectly competitive supplier only gets zero profit because the retailer gets all profit. So, the supplier would like to make a trade credit if there is satisfying Eq. (59.3). Because of the conclusion 1, this condition can be simplified as $E(pq + S(Q - q)) \geq (cQ - \eta)(1 + \theta)$. This condition will be satisfied easily if the retailer has a lot of money. Otherwise, this condition cannot be satisfied, and the trade credit cannot be realized.

From the view of the supplier, if the retailer's money is not enough, the supplier will limit the order quantity in the trade. So, to the supplier, the condition of trade credit is

$$Q \leq \frac{E(pq - Sq) + \eta(1 + \theta)}{c(1 + \theta) - S} = \overline{Q}.$$

It means that the supplier should limit the order quantity below $\overline{Q}$ to get non-negative profit if the retailer cannot pay enough money when ordering products.

Conclusion 4: When the retailer has much enough of money, he can obtain the trade credit easily. Otherwise, the supplier will limit the order quantity to be under

$$\overline{Q} = \frac{E(pq - Sq) + \eta(1 + \theta)}{c(1 + \theta) - S}.$$

We can explain this conclusion qualitatively in an intuitional way. The supplier's profit function is $\pi_s = E[\min[pq + S(Q - q), wQ - \eta] - (cQ - \eta)(1 + \theta)$. And its profit is zero. So, we can draw the supplier's equal profit curve as Fig. 59.1. The value (profit) is zero for every point in the curve. The value is positive for every point above the curve. Otherwise, the value is negative. These means that the supplier will obtain non-negative profit if he can avoid the point is below the curve. According Fig. 59.1, the supplier will limit the retailer's order quantity or ask for a high advance payment to get non-negative profit.

According to the first derivative of $\overline{Q}$, it is obvious that $\overline{Q}$ increases with the retailer's own money, the expected market demand and the salvage value of product increases. When the salvage value per unit S is close to $c(1+\theta)$, the limit of the order quantity will be increased to infinity. This means there is no limit of the order quantity because the product's character of good hedge against inflation could guarantee the supplier's profit. Besides this, the order quantity limit should be raised under the following situations. Firstly, the retailer has a large capital of himself. Secondly, the market demand is high enough. Thirdly, the supplier's cost per unit is low. At last, the opportunity cost is low. The retailer's profit increases when $\overline{Q}$ increases if there is $\overline{Q} \leq Q^*$. So, the retailer without enough capital should choose product which is good hedge against inflation and whose market demand is large to get more profit.

59.7 Conclusions

In this paper, the wholesale price strategy of perfectly competitive supplier and the order strategy of the retailer are studied. Then the credit conditions are discussed based on the game theory and finance theory. Facing the stochastic market demand, the retailer has inventory risk. The retailer will obtain little revenue and cannot pay off the credit loan if he hits low market demand. It means that the trade credit transfers part inventory risk from the retailer to the supplier. Results show that the supplier asks competitive wholesale price which is higher than his product cost per unit. The wholesale price decreases as the retailer's own capital increases and increases as the opportunity cost rate increases. Retailer's order quantity is equal to the integrated supply chain's optimal quantity. But this is based on that the retailer has enough capital as the supplier asks. Otherwise, the supplier will limit the order quantity according to the retailer's own capital to get non-negative profit. When the retailer's order quantity is under the limit, the trade credit will be realized. These conclusions reveal strategies and relationship of both the supplier and the retailer. The trade credit theory is enriched. And some advices are given to the trade credit practice according to this theory.

This study is based on assumes that the supplier is in a perfectly competitive market and the symmetry information. In the practice, there are some more practices under asymmetry information. Some players in the supply chain are partners for a long time not just in a one-time deal. So, the future research will be expanded in these aspects.

Acknowledgments The paper is supported by the China National Natural Science Foundation (Grant No. 70571055), the National Natural Science Foundation China (Grant No.71071103) and the Central Universities Basic Research Funds Special Projects of Sichuan University (Grant No. skq201119). We thank the anonymous reviewer for their helpful comments.

Appendix

Proof We prove conclusion 2 in this appendix.

We denote:

$$G(w) = E[\min[pq + S(Q-q), wQ - \eta]] - (cQ - \eta)(1+\theta).$$

The sufficient is proved at first. Because of $E(pq+S(Q-q)) \geq (cQ-\eta)(1+\theta)$, there is:

$$\begin{aligned} G(w) &= E[\min[pq + S(Q-q), (+\infty) * Q - \eta]] - (cQ - \eta)(1+\theta) \\ &= E(pq + S(Q-q)) - (cQ-\eta)(1+\theta) \geq 0, \end{aligned}$$

and

$$\begin{aligned} G(c) &= E[\min[pq + S(Q-q), cQ - \eta]] - (cQ - \eta)(1+\theta) \\ &\leq \min[E(pq + S(Q-q)), cQ-\eta] - (cQ-\eta)(1+\theta) < 0. \end{aligned}$$

According to the zero point theorem, $w^* \in [c, +\infty]$ exists and satisfies Eq. (59.3).

The necessary is proved by proving his inverse negative proposition. Its inverse negative proposition is that when $E(pq + S(Q-q)) < (cQ-\eta)(1+\theta)$ any $w^*(w^* \in [c, +\infty])$ cannot satisfies Eq. (59.3). If there is $w^* \in [c, +\infty]$ satisfies Eq. (59.3), there is $w^*Q - \eta = (cQ-\eta)(1+\theta)$. According to $E(pq+S(Q-q)) < (cQ-\eta)(1+\theta)$, there is

$$w^*Q - \eta = (cQ-\eta)(1+\theta) > E(pq + S(Q-q)).$$

So, any $w^*(w^* \in [0, +\infty])$ can satisfies

$$G(w^*) = E(pq + S(Q-q)) - (cQ-\eta)(1+\theta) < 0.$$

In a word, there is solution $w^* \in [0, +\infty]$ satisfying Eq. (59.3) if and only if there is $E(pq + S(Q-q)) \geq (cQ-\eta)(1+\theta)$. It is what we wanted to prove.

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Chapter 60
The Trade Credit Will in Supply Chain Transactions

Hong Cheng, Hongmei Guo and Xianyu Wang

Abstract The trade credit is an important way of the enterprise's short-term financing and used wildly. Because of the uncertain market demand, both the retailer and the supplier have the risk of losses. So, they must do the appropriate choose between trade on credit and trade on cash. In this paper, the trade credit will of both sides is studied from the angle of retailer's own funds. The result explains the trade credit threshold in practice. The retailer with any own funds would like to choose trade credit, but the supplier only provides trade credit on certain condition. In the last, some management advices are given to the retailer and the supplier according the analysis, and numerical examples are given to make the theory analysis be visually.

Keywords Stochastic demand · Supply chain · Budget constraints · Trade credit will

60.1 Introduction

The shortage of funds is a common phenomenon in economic and trade all over the world. It hindered the development of enterprises. This case is more common in China. There are some main reasons as following [17]. Firstly, there are many small and medium-sized enterprises which have low credit. Secondly, the commercial bank credit evaluation system is not sound, as well as the single financing form. Thirdly, capital market is lack because it is hard to enter the capital market for the private capital. The last but the most important, there is asymmetry information between the

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_60,

enterprise and the financing institution. Some theoretical studies have shown that the loan provided by the financing institution can be replaced by the trade credit, under some conditions [11, 13]. In 2007, the CGI group's white paper showed that trade credit had taken about 85 % in the global trade [9]. State-controlled listed firms in China receive preferential treatment when borrowing from commercial banks, and in contrast, private controlled firms rely on informal finance and on trade credit which is from suppliers and extended to customers [24]. The uncertainty of market demand brings out inventory risk to retailers. Trade credit transfers party of the risk to the supplier by the form of retailer's default of payment [6, 7]. This case is more common in developing countries because the financial environment is not perfect. So, which choice do the supplier and the retailer will do, trade credit or cash trade?

The existing literatures can be mainly divided into two categories. One kind is studying in the framework of EOQ based on identified demand. The other kind is studying by the newsboy model based on random demand. Most literatures belong to the first kind [15]. In the framework of EOQ model, Harley and Higgins [10], Goyal [8] gave the basic trade credit model to discuss the retailer's optimal inventory strategies. Then, some scholars paid attention to the supplier's credit strategies and supply chain's coordination [2, 20, 23]. The study also extend to product's properties and payment methods [1, 21].

A single enterprise cannot accurately predict his market demand. And the whole demand cannot be accurately predicted, too. So, the retailer faces the risk that the order quantity cannot be sold totally. Trade credit transfers this risk to the supplier partly, because the supplier's credit payment will not be repaid when the selling is bad. For example, during the subprime crisis of USA in 2008, retailers had poor sales or collapsed because the whole market demand decreased.This brought out a lot of bad debts to suppliers. So, the study based on the uncertain market demand is more practical significance.

Considering the uncertain market demand, Cheng et al. [5], Zhang and Luo [25] studied the incentive contract and auction contract about trade credit under the asymmetry information. But they just considered the retailer's risk because of the uncertain demand and ignored the supplier's risk transferred from the retailer because of trade credit. Considering the uncertainty brought risk to both the supplier and the retailer, some research focused on the efficiency and coordination problem of trade credit in supply chain, such as Lai et al. [12], Lee and Rhee [13]. Then Ren and Chen [19] proved that supply chain coordination can be got by adjusting the interest rate of the debt. Chen and Wan [3] proved the existing of equilibrium solution under the whole sale price by use of Stackelberg game. It was considered that the production cost declines and obeys a learning curve phenomenon when studying the optimal trade credit period and order quantity [22]. The study was extended to that the firm provides trade credit to its customer while receiving it from its supplier [16].

The existing literatures including the ahead are based on the assumption that the supplier and the retailer prefer to the trade credit. Their decisions have nothing to do with the retailer's financial strength. But in the real economic activity, not all cash-strapped retailers can access to credit. There is a phenomenon that the supplier does cash trade with the retailer having little money. The supplier provides trade credit when the retailer has a number of money. It is called credit threshold phenomenon. What's the supplier's measure when he makes his decision? How much money does the retailer have when the trade credit can be got. Cheng tried to give an answer when there was moral hazard [4]. An incentive model was established when the retailer had discrete effort. It was the discrete model which made the theory like equity financing not the credit financing.

In this paper, it is considered that trade credit transfers inventory risk partly from the retailer to the supplier. The inventory risk comes from the random demand. From the perspective of retailer's money, the profit is selected to be the index to analyze the credit will of retailer and supplier. The measure of trade credit or cash trade will be given to explain credit threshold phenomenon. Some advices will be given to the retailer and the supplier to get more profit. At last, numerical example will be given to make the theory result more visual.

60.2 Notations and Assumptions

Notations and assumptions used in this paper are giving as following.

1. Notations

q the market demand*,
Q the retailer's ordering quantity,
Q_d the retailer's ordering quantity when he has enough money,
P the price,
c the supplier's unit cost,
w whole sale price per unit product, and $c < w < p$,
η the retailer's own money,
π_r the retailer's expected profit in advance,
π_s the supplier's expected profit in advance.

$*$ is a random between $[0,\ b]$. The distribution function $F(q)$ is continuous differentiable. And it is notated that $\bar{F}(q) = 1 - F(q)$. The density function is $f(q)$.

2. Assumptions

1. q obeys uniform distribution. This assumption was used by many studies [14, 18]. In this condition, there are $F(q) = \frac{q}{b}$ and $f(q) = \frac{1}{b} \cdot b$ is constant. This information is common knowledge of the supplier and the retailer
2. The retail price and the wholesale price are fixed. There are many replaceable products and firms in the market. There are some different sale channels for a kind of product. The cost of management and interest arbitrage will be increased when the price changes in one channel. So the price is fixed is reasonable. For example, the large television manufacturers in China, provides productions to many sale channels with a fixed price.

3. The retailer decides the ordering quantity to maximize his profit and cannot orders again.
4. Retailer doesn't have enough money to pay for the ordering quantity Q_d (which means $\eta < wQ_d$). The retailer and the supplier can choose trade credit or cash trade. When cash trade is chosen, the optimal ordering quantity of retailer is $Q_1 = \frac{\eta}{w}$. When trade credit is chosen, the retailer's optimal ordering quantity is Q^*. He will pay η for part of Q^* and the line of credit is $(wQ^* - \eta)$.
5. The retailer has limited liability. So the supplier has the risk of default payment in the credit transactions. At the end of sale period, the retailer will pay back all arrears $(wQ^* - \eta)$ when the sale is good and the retailer only pay back when the sales are lower than $(wQ^* - \eta)$. In the bad situation, the retailer will file the bankruptcy and the supplier cannot punish the remaining balance.
6. Seasonal product is considered. The salvage is 0 after the selling season.
7. The time cost of money is not considered. In order to simplify the calculation and pay attention to the risk of credit, this assumption is given.

60.3 Models

The capital scope of the retailer, when he has capital shortage, will be given. Then cash trade model and trade credit model are developed and solved when the retailer's money is in the scope. When the retailer has enough money, his expected profit is

$$\pi_{rd} = pQ - \int_0^Q pF(q)d_q - wQ. \tag{60.1}$$

For $\frac{\partial^2 \pi_{rd}}{\partial Q^2} = -pf(Q) < 0$, the retailer's optimal ordering quantity is solved as following from the first order condition of Eq. (60.1):

$$Q_d = F^{-1}\left(\frac{p-w}{p}\right) = \frac{b(p-w)}{p}, \tag{60.2}$$

$\eta < wQ_d = \frac{wb(p-w)}{p} = \eta^0$ means the retailer has capital shortage. So, when $\eta < wQ_d = \frac{wb(p-w)}{p} = \eta^0$, players in the supply chain will do their choice between cash trade and trade credit.

60.3.1 Cash Trade

From the first order condition of the retailer's profit (1), retailer's profit increases with the order quantity when the order quantity is small than Q_d. $\eta < \eta^0$ means $\frac{\eta}{w} < Q_d$. So, in the cash trade, the retailer should put his all money to order more productions to maximize his profit. The order quantity is $\frac{\eta}{w}$. So, profits of the supplier and the retailer are as following:

$$\pi_{s1} = \eta - \frac{\eta}{w}c, \tag{60.3}$$

$$\pi_{r1} = \frac{p\eta}{w} - \eta - \frac{p\eta^2}{2bw^2}. \tag{60.4}$$

When the cash trade is selected when the retailer has capital shortage, $\frac{\eta}{w}$ is the order quantity. Equations (60.3) and (60.4) are the retailer and the supplier's profit.

60.3.2 Trade Credit

When trade credit is selected, expected profit functions of the supplier and the retailer can be written as following:

$$\pi_s = E[\min[p\min[q, Q], wQ - \eta]] + \eta - cQ = (w - c)Q - \int_0^{(wQ-\eta)/p}, \tag{60.5}$$

$$\pi_r = E[\max[0, p\min[q, Q] - (wQ - \eta)]] - \eta = (p - w)Q - \int_{(wQ-\eta)/p}^{Q} pF(q)dq. \tag{60.6}$$

The demand obeys uniform distribution. So, the second order derivative of Eq. (60.6) about Q is negative $\left(\frac{\partial^2 \pi_r}{\partial Q^2} = -\frac{p}{q} + \frac{w^2}{pb} < 0\right)$. So, from the retailer's fist order condition can get the optimal quantity as following:

$$Q^* = \frac{bp^2 - bpw - w\eta}{p^2 - w^2}. \tag{60.7}$$

Simplify Eqs. (60.5) and (60.6) as following:

$$\pi_s^* = (w - c)Q^* - \frac{(wQ^* - \eta)^2}{2bp}, \tag{60.8}$$

$$\pi_r^* = (p - w)Q^* - \frac{pQ^{*2}}{2b} + \frac{(wQ^* - \eta)^2}{2bp}. \tag{60.9}$$

The retailer's order quantity decreases with his own money increasing because there is $\frac{\partial Q^*}{\partial \eta} = -\frac{w}{p^2-w^2} < 0$ from Eq. (60.7). When $\eta = \eta^0$. $Q^* = \frac{b(p-w)}{p} = Q_d$. So $Q^* \geq Q_d$. The reason is that trade credit transfer part of the market uncertainty risk to the supplier for the retailer's limited liability.

The retailer's order quantity is higher in trade credit than in cash trade. It is higher than that in cash trade when the retailer has enough money. It is decrease with the retailer's own money.

60.4 The Trade Credit Will

The trade credit can be realized only if both the retailer and the supplier can obtain more profit than that in cash trade. If any one of them can obtain more profit in cash trade, the cash trade will be selected.

60.4.1 The Supplier's Trade Credit Will

The supplier likes trade credit if he can get more profit in trade credit ($\pi_s^*(\eta) \geq \pi_{s1}(\eta)$). The inequation will be satisfied when η is in some rang. So, the supplier will select trade credit when is in the intersection of the solves of $\pi_s^*(\eta) \geq \pi_{s1}(\eta)$ and $[0, \eta^0]$. The solution will be given in the following.

$\pi_s^*(\eta)$ is concave function about η, because Eq. (60.8)'s second order derivation is negative

$$\left(\frac{\partial^2 \pi_s^*}{\partial \eta^2} = \frac{-p^3}{b(p^2 - w^2)^2} < 0\right).$$

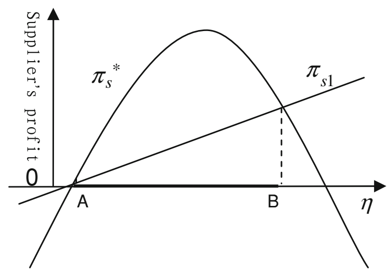
It is obvious that origin is in $\pi_{s1}(\eta)$. So, the figure of $\pi_s^*(\eta)$ and $\pi_{s1}(\eta)$ is as Fig. 60.1. From the figure, the supplier will offer trade credit when the retailer's money is $\eta \in [A, B] \cap [0, \eta^0]$. $[A, B] = \{\eta \mid \pi_s^*(\eta) \geq \pi_{s1}(\eta)\}$, A and B are points of intersection of $\pi_s^*(\eta)$ and $\pi_{s1}(\eta)$, and there is the relationship $A \leq B$.

It is easy to prove the equation $\pi_s^*(\eta) - \pi_{s1}(\eta) = 0$ has solutions and A and B exist.

The symmetry axis of $\pi_s^*(\eta)$ is:

$$\eta_{s0} = \frac{bw(p - w)(p^2 + pc - pw + wc - w^2)}{p^3}.$$

Fig. 60.1 The supplier's profit in different trade



$\pi_{s1}(\eta)$ is a line in which the point (0, 0) and point $(\eta^0, \pi_{s1}(\eta^0))$ is. It should be noted that there are $\pi_s^*(\eta^{(0)} = \pi_{s1}(\eta^{(0)})$ and $\eta_{s0} < \eta^0$. Combining the Fig. 60.1, there is $A < \eta_{s0} < B = \eta^0$. Because the original point is in line $\pi_{s1}(\eta)$, if $\pi_s^*(\eta = 0)$ then $A \leq 0$, otherwise $A > 0$. From the Eq. (60.8), $\pi_s^*(\eta = 0)$ is positive or negative depending on the equation $w^2 - 2wc + 2wp - 2cp$. There is $\text{sgn}(\pi_s^*(\eta = 0)) = \text{sgn}(w^2 - 2wc + 2wp - 2cp)$. So, when $w^2 - 2wc + 2wp - 2cp \geq= 0$, there are $A \leq 0 < B = \eta^0$ and $[A, B] \cap [0, \eta^0] = [0, \eta^0]$. Otherwise, there are $0 < A < B$ and $[A, B] \cap [0, \eta^0] = [A, \eta^0]$.

In conclusion, we can get the conclusion 3 as following:

Conclusion 1: When $w^2 - 2wc + 2wp - 2cp \geq= 0$, the supplier will support trade credit to the retailer with any money. When $w^2 - 2wc + 2wp - 2cp < 0$, the supplier only provides trade credit to the retailer with his money among the rang $\left(\min\{\eta | \pi_s(\eta) - \pi_{s1}(\eta) = 0\}, \frac{bw(p-w)}{p}\right)$.

60.4.2 The Retailer's Trade Credit Will

The retailer likes trade credit only if he can obtain more profit in it than the profit in cash trade, which can be written in mathematical linguistics with $\pi_r^*(\eta) \geq \pi_{r1}(\eta)$. So the retailer will choose trade credit when his own money is in the rang that $\eta \in \{\eta \in \{\pi_r^*(\eta) \geq \pi_{r1}(\eta)\}\} \bigcap [0, \eta^0]$.

From Eq. (60.9), the $\pi_r^*(\eta)$ is a convex function with the symmetry axis $\eta_{r0} = \frac{bw(p-w)}{p}$. From Eq. (60.4), the $\pi_{r1}(\eta)$ is a concave function with the symmetry axis $\eta_{r1} = \frac{bw(p-w)}{p}$ and having the origin in it. It is obvious $\eta_{r0} = \eta_{r1} = \eta^0$. $\pi_r(\eta^0) = \pi_{r1}(\eta^0)$ can be got with simple calculating. So, the figure of $\pi_r^*(\eta)$ and $\pi_{r1}(\eta)$ can be drawn as Fig. 60.2 when there is $\eta \in [0, \eta^0]$. From Fig. 60.2, it is obvious that the retailer with any money will like trade credit because he can get more profit in the trade credit.

Conclusion 2: The retailer with any money prefers to choose trade credit.

The trade credit will be realized only if both the retailer and the supplier have the will of trade credit. In conclusion, although the retailer with arbitrary money prefers to select the trade credit, the supplier will prefer to trade credit only if the

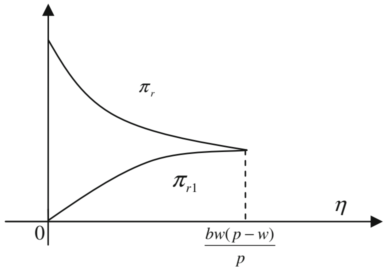


Fig. 60.2 The retailer's profit in cash trade and trade credit

retailer's money is higher than a threshold in some condition. Specifically, when $w^2 - 2wc + 2wp - 2cp \geq 0$, trade credit will be accepted by both. Otherwise, the trade credit will be realized only if the retailer's money is in the range $\left(\min\{\eta|\pi_s(\eta) - \pi_{s1}(\eta) = 0\}, \frac{bw(p-w)}{p}\right)$.

60.5 Strategies Suggestion

The condition in conclusion 1 can be written to a function $g(w) = w^2 - 2wc + 2wp - 2cp$. Because the wholesale price is non-negative, the first order derivation of function $g(w)\left(\frac{\partial g(w)}{\partial w} = 2w + 2(p-c) > 0\right)$ is positive. So, the function $g(w)$ increases with w. It is easy to compute $g(c) = -c^2 < 0$.

When $p < \frac{4c}{3}$, there is $g(p) = 3p^2 - 4pc < 0$. It can be explained that when the profit margin $(p-c)$ is small, the inequation $w^2 - 2wc + 2wp - 2cp < 0$ can be satisfied. The supplier will prefer to provide trade credit when the retailer's money is in the range $\left(\min\{\eta|\pi_s(\eta) - \pi_{s1}(\eta) = 0\}, \frac{bw(p-w)}{p}\right)$.

When $p > \frac{4c}{3}$, there is $g(p) = 3p^2 - 4pc > 0$. So, there must be w^* which is the solve of the equation $g(w) = w^2 - 2wc + 2wp - 2cp = 0$. When $w \geq w^*$, there is $g(w) = w^2 - 2wc + 2wp - 2cp \geq 0$ because of the monotonicity of $g(w)$. When $w < w^*$, there is $g(w) = w^2 - 2wc + 2wp - 2cp < 0$. Combining the conclusion 1, if the industry marginal profit $(p-c)$ is big, when the supplier's marginal profit is high (which means the wholesale price is high), he will provide trade credit to the retailer which has arbitrary money. When the supplier's marginal profit is low (which means the wholesale price is low), he will provide trade credit to the retailer whose money is in the range $\left(\min\{\eta|\pi_s(\eta) - \pi_{s1}(\eta) = 0\}, \frac{bw(p-w)}{p}\right)$.

From the theory analysis above, qualitative advices can be provided as following. To get more profit, the supplier should provide trade credit to every retailer when the industry marginal profit $(p-c)$ and his own marginal profit $(w-c)$ are high. Otherwise, the supplier should control the trade credit and only provide trade credit to the retailer whose money is in the range $\left(\min\{\eta|\pi_s(\eta) - \pi_{s1}(\eta) = 0\}, \frac{bw(p-w)}{p}\right)$. The specific quantitative judgment should refer to the conclusion 1.

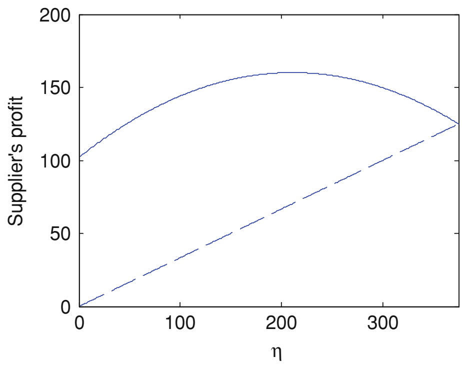


Fig. 60.3 The supplier's credit will

If the industry marginal profit and the supplier's marginal profit are low, the retailer will be limited by the credit threshold, which means if the retailer's capital is lower than $\{\eta|\pi_s(\eta) - \pi_{s1}(\eta) = 0\}$ he cannot get the trade credit. Retailer's capital is constituted with his cash and the collateralizable assets. Because the retailer's collateralizable assets has the same role with the cash and it can be used to pay the supplier if the retailer cannot pay the debt. The collateralizable asset is constituted with the physical assets and intangible assets. The physical assets and cash are the tangibles which are accumulated in the process of operation management. The intangible is the accumulation of the goodwill. So, to get more profit, the retailer should take actions to increase the credit threshold. For example, he can improve both tangible and intangible.

60.6 The Numerical Example

The matlab7.0.1 is used to compute and draw figure to verify the theory conclusions. Two situations, which are the supplier's margin profit is big ($w^2 - 2wc + 2wp - 2cp \geq 0$) and it is small ($w^2 - 2wc + 2wp - 2cp < 0$), are considered respectively.

60.6.1 The Supplier's Margin Profit is Big

Suppose the retail price $p = 10$, the wholesale price $w = 7.5$, the cost per unit $c = 5$, the constant $b = 200$. These parameters satisfy the condition $w^2-2wc+2wp-2cp > 0$ (the retailer's margin profit is big). Under this assignment, the retailer's capital threshold is $\eta^0 = 375$. It means if the retailer's capital is in the rang $\eta \in [0,375)$, he has capital constraint.

The condition that the supplier prefer to trade credit ($\pi_s(\eta) > \pi_{(s1)}(\eta)$) is shown in Fig. 60.3. The dotted line is $\pi_{s1}(\eta)$ and the solid line is $\pi_s(\eta)$. The capital range in

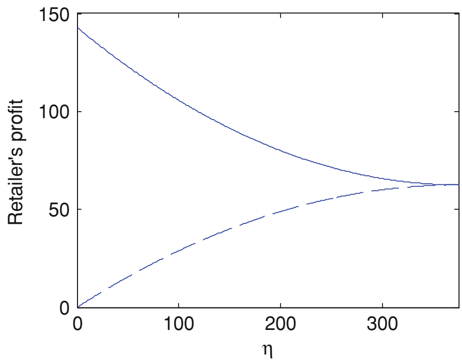


Fig. 60.4 The retailer's credit will

which trade credit can be realized is $\eta \in [0,375)$ by computing. It means the retailer with any capital will get the trade credit from the supplier.

The condition that the retailer prefer to trade credit ($\pi_r(\eta) > \pi_{r1}(\eta)$) is shown in Fig. 60.4. The dotted line is $\pi_{r1}(\eta)$ and the solid line is $\pi_r(\eta)$. It is easy to find that the retailer with capital in the range $\eta \in [0,375)$ will prefer trade credit. It means that the retailer with any capital would like trade credit.

In conclusion, when the supplier has large margin profit which means $w^2 - 2wc + 2wp - 2cp \geq 0$, both the supplier and the retailer would like trade credit no matter how much capital the retailer has.

60.6.2 The Supplier's Margin Profit is Small

Assign number to parameters as following: the retail price $p = 10$, the wholesale price $w = 6$, the cost per unit $c = 5$ and the constant $b = 200$. These assignments satisfy the condition $w^2 - 2wc + 2wp - 2cp > 0$. It is easy to get the capital threshold $\eta^0 = 480$. It means if the retailer's capital is in the range $\eta \in [0,480)$ he has capital constraint.

The supplier prefers to trade credit under the condition $\pi_s(\eta) > \pi_{s1}(\eta)$. It is drawn in Fig. 60.5. The dotted line is $\pi_{s1}(\eta)$ and the solid line is $\pi_s(\eta)$. It is easy to get that if the retailer's capital is in the range $\eta \in (160/3,480)$, the supplier would like to provide trade credit.

The condition under which the retailer would like to trade credit ($\pi_r(\eta) > \pi_{r1}(\eta)$) can be drawn like Fig. 60.4. It is easy to get that when the retailer's capital is in the range $\eta \in [0,480)$ he would like trade credit.

In conclusion, when the supplier has small margin profit (which means $w^2 - 2wc + 2wp - 2cp < 0$), the trade credit can be realized if the retailer's capital is in the range $\eta \in (160/3,480)$.

Two numeral examples illustrate the conclusions 1 and 2. The retailer prefers trade credit no matter how much capital he has. The supplier's choice depends on his

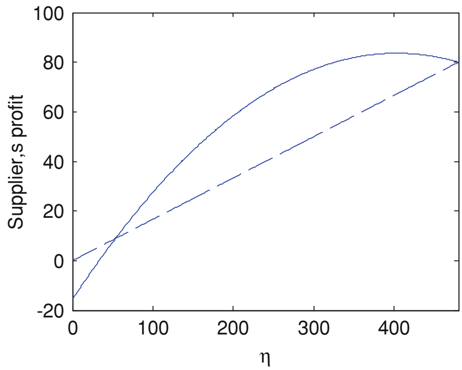


Fig. 60.5 The supplier's trade credit will

margin profit. When he has large margin profit he would like trade credit. Otherwise, he would like to provide credit to the retailer who has big capital. This is the credit threshold in economic practice.

60.7 Conclusions

Trade credit transfers part of the inventory risk because of the random demand from the retailer to the supplier. So, the supplier should consider the trade credit carefully. This paper focuses on this from the perspective of retailer's capital. The credit will of both the retailer and the supplier by comparing the profit in cash trade and trade credit. Analysis results shows that the retailer with any capital can get the trade credit if the supplier's margin profit is large and only the retailer with much capital can get trade credit if the supplier's margin profit is small. It explains the phenomenon that small stores cannot get trade credit and provide theory proof for credit decisions. The conclusions provide some inspirations. To get more profit the supplier should limit the trade credit strictly depending on his margin profit and the retailer's capital. To get more profit, the retailer should try his best to improve his tangible and intangible. Numerical example is given to illustrate the conclusions.

In economic practice, the hypothesis about information symmetry does not exist. Each economic subject is individual and has his private information. It brings about adverse selection and moral hazard. Another hypothesis about the wholesale price exists in practice but not in every trade. In some situation, the wholesale price will change depending the order quantity or credit amount. There are credit contracts and payments in practice which are more complicate than that in this paper. All these assumptions in this paper can be gradually relaxed in future study. This study lays the foundation for subsequent study.

Acknowledgments The paper is supported by the National Natural Science Foundation China (Grant No. 71071103), the Ministry of Education, Humanities and Social Science Planning Fund for the Western and Frontier (Grant No. 13XJC630014) and the Central Universities Basic Research Funds Special Projects of Sichuan University (Grant No. SKQ201119). We thank the anonymous reviewer for their helpful comments.

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Chapter 61
Supply Chain as a Collaborative Virtual Network Based on LARG Strategy

Ana Rolo, António Ramos Pires and Margarida Saraiva

Abstract The structure, organization and integration it is crucial to improve global supply chains performance and help them to achieve strategic and operational goals. Literature suggests that agile, resilient and sustainable supply chains strategies enable them to be more competitive in order to adapt to the dynamic and unstable scenario. This paper aims to present a model for implementing a strategy based on LARG paradigms (Lean philosophy, Agility, Resilience and sustainability—"Green"), used to denote the necessary strategy for competitiveness in an international automotive supply chain. Using "building theory approach", supported by a case study, conducted in four companies that integrated automotive supply chains, three hypotheses were defined to be validated through an explanatory model and Key Performance Indicators (KPI's) were defined to measure supply chain overall performance. This study brings contributes to management knowledge by empirically investigate the main effects of LARG strategy on supply chain performance, proposing a process approach applied to a collaborative virtual network structure, in order to improve network efficiency. Data analysis supports some interesting conclusions, as the more important KPI's to measure LARG strategy, and the evolution from Supply chain to Supply Network.

Keywords Supply chain · Collaborative network · Lean · Agile · Resilient and green supply chain

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_61,

61.1 Introduction

Presently, the economic activities are global, so companies are aware that they cannot compete alone, being much easier to join up and do it [13]. This reality has led companies to develop new models of relationship, for example, cooperation management network model, that aims the effectiveness and efficiency of investments in resources, production and distribution of products or services, which allows them the ability to work as a single unit in real time on a planetary scale [4]. These networks are strong business alliances whose approach involves the integration of business and strategy, with the purpose of increasing the collective competitiveness, which requires a great coordination of activities and internal and external processes.

This paper presents the results of a case study in automotive industry, from the perspective of the inter-organizational network relationships, based on LARG strategy. The article is structured in five sections; it starts with a literature review in the first section, which seeks to clarify the notion of supply chain and supply network or cooperation network and "LARG" strategy. In the second section, network Key Performance Indicators were suggested and a proposal of conceptual model is presented. The third section describes the methodology used. In the fourth section, the preliminary results of the empirical study on developing a supply network in the automotive industry are presented. And the section five presents the main conclusions.

61.2 Literature Review

61.2.1 From Supply Chain to Supply Network

The concept of supply chain has evolved over time. In the past, vendors developed one to one relationships with their customers, protecting these relationships, projects and innovations; currently, these relations have evolved from various to many, working together, sharing resources, and reducing costs. Various supply chain definitions who question the linear view (chain), advocating a radial view (network) are arising (Fig. 61.1, source: adapted from [11]).

"A supply chain collaborative network, refers to an integrated network of entities that associate with each other in a business environment, where the entities can be suppliers, manufacturers, distributors, retailers and customers" [8].

Harland [7] corroborate this thought that a supply chain it is more a network, than a chain. Based on this approach, the supply chain in this paper was analyzed as a network of cooperation between customers, suppliers and distributors.

61.2.2 Supply Chain Network Design

Vertical integration, which in the past allowed the companies to assure all or part of the production process, does not allow sufficient agility and resiliency, and economies

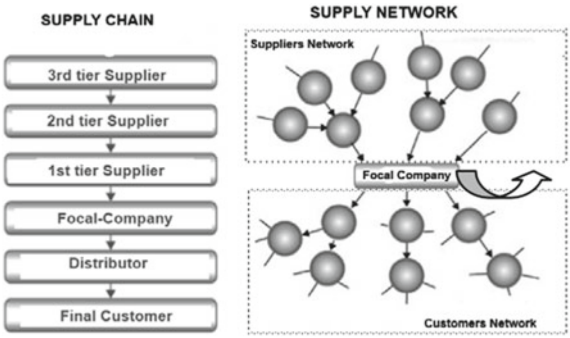

Fig. 61.1 From supply chain to supply network

of scale necessary for competitiveness in the current market too unstable. All companies tend to be part of a supply chain, or even several. Business networks, dynamic networks or "webs of interest", appear as new forms of relationship and cooperation between companies to cope with the strong competition, the dynamics and the instability caused by the phenomenon of globalization, which has led to a market highly competitive.

Networking is an concept that designates the organization or network structure enabling collaboration between organizations and enables that facilitate its presence in various markets without having to be located in that place. This is only possible due to the development of Information and Communication Technology (ICT), providing a link between computers for multiple users located anywhere in the world and thus enabling the "shared data access", securing remote operations. Watts [16] argues that networks are dynamic because its elements are always in action, evolving with time. The organizations that comprise a network collaborate with their biggest skills, share information, communicate electronically, optimize the available resources, establish a cooperative relationship between the global dimension itself, overcoming the limits of time and distance between the partner organizations, or between the organization and the customer.

According to Pereira et al. [14], "networks are multi-organizational arrangements to solve problems that cannot be addressed, or addressed easily through a single organization". Another definition given by Pereira et al. [14] inserts the organizational design, a contemporary vision of virtual organizations, and network organization defines as "a set of relatively stable relationships, non-hierarchical and interdependent nature, linking a variety of actors who share common interests with respect to a policy and who exchange resources to meet these shared interests, recognizing that cooperation is the best way to achieve common goals".

A supply network is comprised of various entities, whose activity can be clearly distinguished. The structure and organizational culture, decision-making processes and management models vary from company to company. So there is not a common environment, which arises as a constraint to the definition of a structure and common strategy.

Supply chain network design is a strategic tool used to evaluate and recommend physical changes in supply chain, e.g. related to inbound movement of raw materials from suppliers, storage locations; manufacturing locations, and outbound of final products from storage locations and movement to customers, with the purpose of improve operations margins and asset utilizations and maintain service levels.

The importance of supply chain design is related with its impact on supply chain fixed costs. Adopting strategic supply chain network design, companies can achieve considerable cost reduction. However, design changes are decisions that require effort and cost, whereby it is important to make a detailed analysis of outcomes and scenarios (optimistic, pessimist and realistic). New products, new markets to serve, new strategy, alternative transportation modes for example, are situations that could trigger a new supply chain network design.

To manage supply network it is necessary to define a common strategy, setting the best way to operate the whole net, and maximizing value creation through the design of an efficient modeling of the structure and design of the network. The goal is to achieve optimization, maximum financial value and competitive advantage from their operations. The new design should allow integration between all network elements. If a producer adopts the best practices and its suppliers adopt "the worst" practice, e.g. excessively high prices, or inefficient distribution channels in meeting customer expectations, so, in this cases the network performance is compromised. The main challenge is the co-creation of value, and the fair distribution of benefits in order to encourage active participation of each partner.

Organizational design was refer by contingency theories as the process of choosing and implementing a structural setting, and suggest that organizational structure must be designed to accommodate the company's strategy [5] and environmental uncertainty [9]. In the case study, the organizational design related to the network structure must also accommodate LARG strategy approach, described below.

KPI's, process management approach, as well as the management bodies of the supply network as a whole are other issues needing answers.

61.2.3 LARG Strategy

To cope with the strong competition and the instability caused by globalization, and convinced that the results depends on the strategic and structural choices, and also the process model, some characteristics considered essential for the survival of a pipeline in the industry automobile were identified. Lean approach presents itself as the dominant paradigm in this sector and enables improvements in productivity, quality, flexibility and adaptability of production to new economic, technological, social or environmental requirements operations. This strategy, focused on Lean philosophy, will have a positive impact on the management and performance of the network, helping to organize resources more efficiently, minimizing or eliminating waste, reducing stocks by the use of Just in Time (JIT) and Just in Sequence (JIS) methodology techniques.

Agility and resilience appear to be necessary to ensure rapid, appropriate and effective response to changes and cope with the instability and turbulence, which can lead to change and readjustment processes and work flows essential for network management and inevitably to new organizational configurations, which may involve changes in the relationships between the various stake holders as well as methods, processes and practices, and that will be reflected in the structure defined to the network.

The agile supply chain has the ability to respond quickly to customer requests and market changes. The importance of this attribute is related to the degree of customers' requirement, the life cycles of products and services the increasingly shorter and the technological development. This agility can be achieved through the products innovation, process innovation or organizational innovation, by new structuring of relations between the network partners.

Resilient supply network has the ability to adapt to disturbances (e.g. complex situations, crisis, and strikes). Networks should develop a "culture of resistance" and adaptability, being able to serve as a catalyst to increase group cohesion, because the network is not homogeneous and the most "fragile" companies may have greater difficulty in dealing with this type of phenomena/events. It is important to strengthen the resilience throughout the network.

Finally, the green supply network aims to minimize environmental impacts and increase the sustainability of the network. During the last decade, the growth of environmental awareness, in the European organizations, governments and consumers in general, has boosted the development of policies for environmental sustainability and production and marketing of environmentally friendly products, creation of more restrictive legislation and the monitorization of the effectiveness measures.

Carvalho et al. [3] submit that the simultaneous integration of the four LARG paradigms in the management of the supply chain can lead to supply chain efficiency, rationality and sustainability. However, different paradigms seem to be related conversely. For example, lean production, works in JIT or JIS, which presupposes the absence of stock or stock keeping close to zero. However, a resilient supply network should work with enough stock to allow it to react to the effects of a rupture or other disorder. This seems contradictory, and achieves the balance between these two attributes presents itself as a huge challenge. Balancing the four LARG attributes into a single strategy is presented as an even greater challenge.

61.3 Conceptual Model

A model is a tool, used to represent a reality and in order to understand, change, manage and control part of that reality. Models are abstractions or simplified representations of reality that help us understand the reality and act on it.

It seeks to present a model that put together a LARG quality approach and supply network management, based on the process approach, guiding companies, from defining the business strategy to the integration of the supply chain, assisting in the identification and definition of information needs, human resources, management and quality control.

Meixell and Gargeya [12], dedicated themselves to the study of models for decision support in global supply chains, based on a classification focused on emerging issues, that include the schema: the dimensions for making decisions; performance measures; the degree in which the model supports integrated decision processes and globalization. They concluded that, while most models solve the problem associated with globalization, few address the practical problem of the design of global supply chain in whole.

The process approach applied to the definition of new organizational solutions have shown to be a very effective and easy deployment model to achieve results in the field of quality, and this allows to align the organization's processes with the goals to achieve, and then to perform the tasks effectively and efficiently. According to Pires [15], while process management is an instrument of horizontal coordination, the hierarchy established by the functional structure coordinates the allocation of staff and resources in their area of expertise.

The process approach presupposes the definition of processes, metrics and indicators for monitoring these processes, as well as the management responsibilities, aiming to increase productivity.

61.3.1 Network Key Performance Indicators

In a collaborative supply chain network, performance measurement is essential. It is the stage of monitoring and evaluation. According to Shah and Singh (apud Lam [8]), an appropriate performance measurement can help to measure and evaluate the effectiveness of a supply chain, and the analysis of the performance can help the enterprises to further improve the supply chain management of network.

Key Performance Indicators are measures of process performance in organizations are used as communication tools between top management and hierarchical levels below, since they reflect the mission and vision. KPIs can also be used for performance measurement of a supply network, allowing it to direct its goals and quantifying its effectiveness and efficiency. To evaluate supply network performance it is important to define KPIs that will measure different types of performance: economic, operational and environmental.

Economic performance is affected by the management of the supply network, whose impact can be measured in terms of sales, purchasing policy, operating expenses, and investment needs (e.g. R&D, technology, marketing, stocks). Economic performance is also affected by operational and environmental performance.

At the operational level is important to distinguish between the activities of production and logistics. Examples of indicators that measure the operating performance

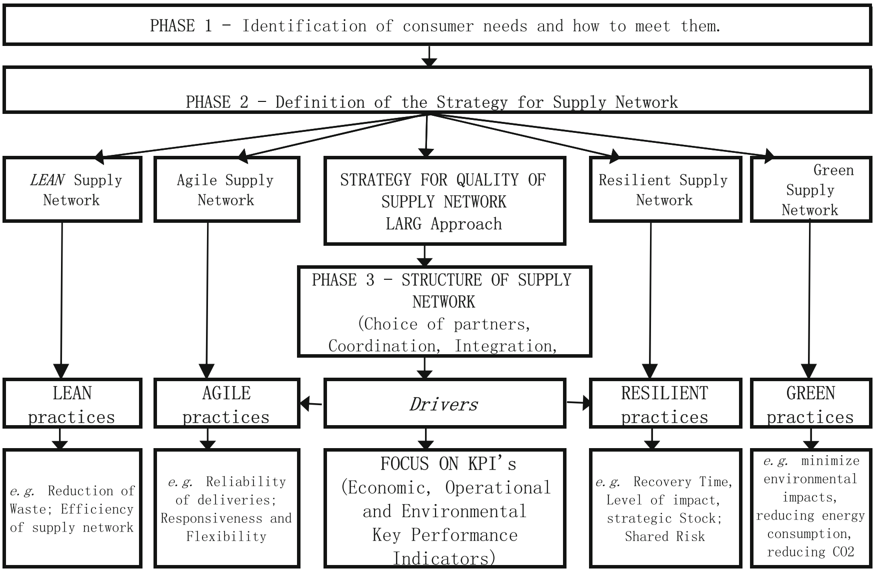

Fig. 61.2 Framework of LARG strategy implementation process

are: quality level, number or percentage of defects, delivery reliability, lead time delivery, flexibility and responsiveness to changes in demand.

Environmental performance can be optimized by implementing environmental awareness programs, and can be measured by environmental indicators; e.g. the reduction of energy consumption and atmospheric emissions of carbon (ecological footprint), the number of programs on environmentally conscious production implemented, the percentage of recovered and recycled materials, the treatment of solid and liquid waste.

According to Azevedo et al. [2], between the LARG practices, the ones that most influence the performance of the supply chain is the implementation of JIT (Just in time) and the relationship with suppliers. Operational performance of the network, is also influenced by the "lead time" and the levels of stock, so the maintenance of low levels of stock, will contribute to the optimization of network performance.

The lead time and reliability of delivery are important performance indicators of the supply networks, since a delay by a supplier of materials, parts, or components or logistics operator may result in stoppage of the production line, and therefore many thousands of dollars of damage, and unhappy customers. Control of lead time between a company and a supplier is so critical and allows controlling the lead time between now and the end customer.

In order to facilitate the conceptual translation of the network organization and structure, a framework was designed (Fig. 61.2). It defines the phases for implementation to be easier to implement. The Phase 1 identification of consumer needs and how to meet them encompasses the processes of demand management as well as

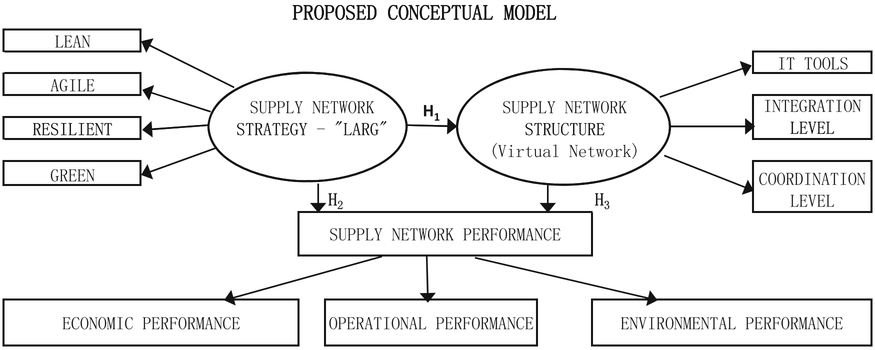

Fig. 61.3 Proposed conceptual model

design and development of products and processes. The definition of the strategy and structure for the network (Phase 2 and 3), includes the remaining processes that should be taken into account. Drivers are defined in alignment with strategy and provide the basis for defining indicators to measure them (Operational, Economic and Environmental KPIs).

61.3.2 Conceptual Model

This paper aims to propose a model that translate the importance of network LARG strategy, in network structure definition and in supply network performance to understand if it is a strategy to follow. The conceptual model it will be presented and will be tested later, based on a questionnaire survey with the aim of seeking to answer the three hypotheses (Fig. 61.3), namely:

Hypothesis H1. The LARG approach strategy positively influences the structure of the supply network.

Hypothesis H2. The virtual structure of the supply network, positively influences the performance of the supply network.

Hypothesis H3. The LARG approach strategy positively influences the performance of the supply network.

Structural equation modeling will be used to validate the proposed model. The questionnaire survey is now available in Google Docs platform, to be answered. At the moment only the qualitative data obtained through semi-structured interviews are available, and will be presented.

61.4 Research Metodology

To validate some theoretical knowledge, namely the way supply network establish strategies and structural formats, a case study has been conducted in a Multinational Car Manufacturer MCM located in Portugal, and three of their 1st tier suppliers.

The data collection procedures consisted on interviewees to the middle and senior level staff of Supply Chain, Quality and Production departments.

The case study methodology allowed to collect and analyze both quantitative and qualitative data, observe behavior in its natural context and conduct interviews, administer tests or questionnaires applied [17].

In this particular case, has provided a thorough knowledge of a group of companies that integrate a supply network within an industry, which is a limitation, but also a motivation to pursue more comprehensive future work.

In constructing the semi-structured interviews, the assumptions of Lipnack and Stamps [10], Casarotto Filho and Pires [6] were used, as well those of Almeida [1] with regard to the activities and processes integrated into networks of cooperation between companies. The studies of Azevedo et al. [2] and Carvalho et al. [3] were used with regard to LARG approach.

61.5 Case Study: A Multinational Car Manufacturer

MCM is an automotive industry company. The case study examined a supply network in the automotive industry, the car producer and three of the 1st tier suppliers.

The supply network was involved in the daily operation and manufacturing supply network of the fourth entities.

Data collection aimed to study the impact of LARG strategy on organizational design or structure and on network performance. Through the auscultation of the management we attempted to:

1. Identify the importance of LARG strategy;
2. Identify and characterize the current supply network strategy;
3. Identify and characterize the current organizational structure and relationship with the 1st tier suppliers;
4. Understand what changes occurred in the strategy or in the structure;
5. Identify the importance of innovation in the organization's strategy and what were the major events of change.

Strategy based on LARG paradigm was considered very appropriate to deal with the current economic climate and with the unstable and turbulent market; "perhaps the one that will lead to good results and for survival" (was one of the answers).

In Automotive industry, quality was always the more important driver in the network strategy. All the companies betted on a culture of excellence and continuous improvement, that continues to be valued. Furthermore, all the companies consider that LARG strategy and the use of Key Performance Indicators to support management, is very important too. However, both, the LARG strategy as the use of KPI were defined at the individual level and not at the network level as would be desirable.

When we asked about the ideal design to the collaborative supply network, 68 % of the interviewers choose the virtual network structure, in order to improve network efficiency and agility, supported by Information Technologies (e.g. EDI, CRM, ERP).

The changes that were most frequently mentioned by the directors were: stock reduction in order to costs reduction; environmental programs like "Think Blue Factory" in order to reduce energy consumes and carbon impact on environment; policy of long term relationship with suppliers in order to develop them.

The directors are unanimous in agreeing that innovation is a very important to contribute to the agility of business in response to market demands, technological development and decrease of products life cycle. Innovation can occur in products, but it is also very important in terms of processes and information systems to support the processes of coordination and integration of partners in the network.

61.6 Conclusions

All interviewers were unanimous to accept that the supply chain concept has evolved to supply network.

This supply network relies on information and communication technology, which gave it a collaborative virtual network features. This format facilitated communication and allowed you to connect companies that are physically distant; causing the problem of distance is exceeded.

The LARG strategy and the definition of key performance indicators were still defined for each company individually. Mechanisms should be established to define the strategy and the Key Performance Indicators to the network as a whole and not just in an individual level.

From the point of view of organizational design applied to a network, the network would be expected to have a structure and strategy as well as a management entity, a network of transverse processes to various organizations, together with their managers and monitoring indicators.

Specifically in terms of the forms of network management, only the realization of weekly meetings between the supply chains teams of MCM and local suppliers were found. Thinking in terms of other areas of integration between the companies' processes, no solutions have been identified, except those relating to the transaction of raw materials between suppliers and customers. Even these were restricted to the monitoring of production needs and the flow of materials. No indicators were used to evaluate network performance.

Given the objectives of the investigation, we found no organizational management practices inside this network where we could find support to define a methodology for designing supply networks. Thus, we will define a conceptual methodology, for which we will invite the businesses leaders to give their opinion about its validity and opportunity.

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Chapter 62
Supplier Evaluation and Selection Using Restricting Weights Method in Fuzzy Environment

Abid Hussain Nadeem, Muhammad Nazim, Muhammad Hashim, Muhammad Kashif Javed and Liming Yao

Abstract Data envelopment analysis (DEA) is a method for supplier selection. Weight restrictions allow for the integration of managerial preferences in terms of relative importance levels of various inputs and outputs. In some situations there are some factors which play both input and output roles as well. The purpose of this research is to propose a method for selecting the best suppliers in the presence of weight restrictions and dual-role factors. This study shows the supplier selection process through a DEA model, while allowing for the incorporation of decision makers preferences and considers multiple factors which simultaneously play both input and output roles. The proposed model does not demand exact weights from the decision maker. This study presents a robust model to solve the multiple-criteria problem. A numerical example certifies the application of the proposed method.

Keywords Data envelopment analysis · Supplier selection · Weight restrictions · Dual-role factors

62.1 Introduction

Supplier selection is a key operational task for developing sustainable supply chain partnerships. Currently, due to outsourcing initiatives, organizations have become more dependent on suppliers making it more critical to choose and evaluate their supplier performance. Supplier evaluation and selection requires the consideration of multiple objectives and criteria [3].

First, multiple sourcing prevents suppliers from achieving the economies of scale based on order volume and learning curve effect. Second, multiple supplier system

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_62,

can be more expensive than a reduced supplier base. For instance, managing a large number of suppliers for a particular item directly increases costs, including the labor and order processing costs to managing multiple source inventories. Meanwhile multiple sourcing lowers overall quality level because of the increased variation in incoming quality among suppliers. Third, a reduced supplier base helps eliminate mistrust between buyers and suppliers due to lack of communication. Fourth, world-wide competition forces firms to find the best suppliers in the world. The extensive nature and modeling complexity of the regular supplier selection process makes the problem heavily reliant on multiple criteria decision models. This real world complexity in the outsourcing and vendor selection process generated the need to help organizations make more thoughtful and simplified decisions.

Simplifying complex managerial decision making is the role of many pragmatic theories and models [18]. Supply chain management has become a key aspect that has implications for effective and efficient management of industrial relations. It has also become an important focus for firms and organizations to obtain a competitive advantage [4].

Models for supplier selection represent only one of over a dozen supply chain management areas (a comprehensive review of supply chain modeling literature) [1].

A fuzzy relations-based AHP was applied to supplier segmentation. Scientifically, the application of fuzzy-based AHP to these types of problems is highly relevant. In general, methods based on fuzzy sets theory seem to be a perfect fit to the inherent complexity and fuzziness of constructs in the management sciences [12].

One of the uses of data envelopment analysis (DEA) is supplier selection. In original DEA formulations the assessed decision making units (DMUs) can freely choose the weights or values to be assigned to each input and output in a way that maximizes its efficiency, subject to this system of weights being feasible for all other DMUs. This freedom of choice shows the DMU in the best possible light, and is equivalent to assuming that no input or output is more important than any other. The free imputation of inputCoutput values can be seen as an advantage, especially as far as the identification of inefficiency is concerned. If a DMU (supplier) is free to choose its own value system and some other supplier uses this same value system to show that the first supplier is not efficient, then a stronger statement is being made. For example, in supplier selection problem in general, one input (material price) usually overwhelms all other inputs, and ignoring this aspect may lead to biased efficiency results. Suppliers might also supply some outputs that require considerably more resources than others and this marginal rate of substitution between outputs should somehow be taken into account when selecting a supplier. To avoid the problem of free (and often undesirable) specialization, input and output weights should be constrained in DEA. In some situations there is a strong argument for permitting certain factors to simultaneously play the role of both inputs and outputs. In supplier selection context, the research and development cost can be considered as both an input and an output. Remembering that the simple definition of efficiency is the ratio of output to input, an output can be defined as anything whose increase will cause an increase in efficiency. Similarly, an input can be defined as anything whose decrease will cause an increase in efficiency. If the research and development cost is considered as an output, then the increase in the research and development cost will increase the efficiency of the supplier. Likewise, if the research and development cost is considered as an input, then any decrease in the research and development cost without a proportional decrease in the outputs will increase efficiency. So, depending on how one looks at it, either increasing or decreasing the research and development cost can increase efficiency [15].

In order to increase a company's competitive advantage in supply chain management, enterprises have to maintain long-term relationships with their most reliable suppliers. When companies select the right suppliers, cost is not the only criterion to be considered; companies also need to consider quality, deliverability, and service [10].

Generally speaking, the criteria for supplier selection highly depend on individual companies and industries. On the one hand, different companies have different organizational structure, management strategy, enterprise culture and others. All of these influence the determination of supplier selection criteria. On the other hand, industry background causes huge difference and greatly impacts the selection of suppliers. Therefore, the identification of supplier selection criteria are on the basis of specific environments, and largely requires domain experts' assessment and judgment [9]. Supplier selection highly depends on large amounts of domain knowledge, where experts' assessments play an important role. However, various uncertainties are present in domain experts' subjective and qualitative judgment, such as imprecision, fuzziness, incompleteness and so on. Therefore it is necessary to develop a more effective method for supplier selection, which should be able to handle various types of uncertainties [11].

62.2 Proposed Method for Supplier Selection

DEA proposed by Charnes et al. [5] (Charnes-Cooper-Rhodes (CCR) model) and developed by Banker et al. [2] (Banker-Charnes-Cooper (BCC) model) is an approach for evaluating the efficiencies of DMUs. One serious drawback of DEA applications in supplier selection has been the absence of decision maker judgment, allowing total freedom when allocating weights to input and output data of supplier under analysis. This allows suppliers to achieve artificially high efficiency scores by indulging in inappropriate input and output weights.

The most widespread method for considering judgments in DEA models is, perhaps, the weight restrictions inclusion. Weight restrictions allow for the integration of managerial preferences in terms of relative importance levels of various inputs and outputs. The idea of conditioning the DEA calculations to allow for the presence of additional information arose first in the context of bounds on factor weights in DEA's multiplier side problem. This led to the development of the cone-ratio [6] and assurance region models [17]. Both methods constrain the domain of feasible solutions in the space of the virtual multipliers. The discussions in this paper are provided with reference to the original DEA formulation by Charnes et al. [5] below, which assumes constant returns to scale and that all input and output levels for all DMUs are strictly positive. The CCR model measures the efficiency of DMU_o relative to a set of peer DMUs:

$$\begin{cases} e_o = \max \dfrac{\sum_{q=1}^{t} g_q u_{qo}}{\sum_{r=1}^{k} h_r v_{ro}} \\ \text{s.t.} \begin{cases} \dfrac{\sum_{q=1}^{t} g_q u_{pq}}{\sum_{r=1}^{k} h_r v_{pr}} \leq 1, \quad p = 1, \cdots, n \\ g_q, h_r \geq \varsigma, \qquad \forall \ q \text{ and } r. \end{cases} \end{cases} \tag{62.1}$$

Problem parameters:
$\lambda_r, \gamma_r, \varepsilon_q, \mu_q, \Omega_r, \Phi_r, \beta_q, \vartheta_q, \varpi_r, d_q, c_q, a_r, b_r$: user-specified constants,
$p = 1, \cdots, n$ collection of suppliers (DMUs), $q = 1, \cdots, t$ the set of outputs,
$r = 1, \cdots, k$ the set of inputs, $f = 1, \cdots, F$ the set of dual-role factors,
U_{qp} = the qth output of pth DMU, V_{pr} = the rth input of pth DMU,
U_{qo} = qth outputs of the DMU_o under investigation,
V_{ro} = rth inputs of the DMU_o under investigation,
Z_j = the factor that plays the role of both an input and output,
Z_{fp} = the fth dual-role factor of pth DMU Decision variables,
g_q = weight of the qth output, h_r = weight of the rth input,
where there is a set of n peer DMU_t, $DMU_p : p = 1, 2, \cdots, n$, which produce multiple outputs U_{qp} $(q = 1, 2, \cdots, t)$, by utilizing multiple inputs V_{pr} $(i = 1, 2, \cdots, m)$. DMU_o is the DMU under consideration. g_q is the weight given to output q and h_r is the weight given to input r. ς is a positive non-Archimedean infinitesimal. DMU_o is said to be efficient. $(e_0 = 1)$ if no other or combination of DMU_t can produce more than DMU_o on at least one output without producing less in some other output or requiring more of at least one input. The linear programming equivalent of Eq. (62.1) is as follows:

$$\begin{cases} e_o = \max \sum_{q=1}^{t} u_{qo} g_q \\ \text{s.t.} \begin{cases} \sum_{r=1}^{k} v_{ro} h_r = 1 \\ \sum_{r=1}^{k} v_{pr} h_r - \sum_{q=1}^{t} u_{pq} g_q \geq 0, \ \forall \ p \\ h_r \geq \varsigma \ \forall \ r \\ g_q \geq \varsigma \ \forall \ q. \end{cases} \end{cases} \tag{62.2}$$

In Eqs. (62.3)–(62.5) the various types of weight restriction that can be employed to multiplier models are shown [8].

Absolute weight restrictions:

$$\lambda_r \leq h_r \leq \gamma_r \ \ (a_r), \quad \varepsilon_q \leq g_q \leq \mu_q \ \ (a_o). \tag{62.3}$$

Assurance region of type I:

$$\Omega_r \le \frac{h_r}{h_{r+1}} \le \phi_r \ \ (b_r), \quad \beta_q \le \frac{g_q}{g_{q+1}} \le \vartheta_q \ \ (b_o). \tag{62.4}$$

Assurance regions of type II:

$$\varpi_r h_r \ge g_q \ (c). \tag{62.5}$$

These letters $(\lambda_r, \gamma_r, \varepsilon_q, \mu_q, \Omega_r, \Phi_r, \beta_q, \vartheta_q, \varpi_r)$ are user-specified constants to reflect value judgments the decision maker wishes to incorporate in the assessment. They may relate to the perceived importance or worth of input and output factors. The restrictions (a) and (b) in (62.3)–(62.5) relate on the left hand side to input weights and on the right hand side to output weights. Constraint (c) links directly input and output weights. Absolute weight restrictions are the most immediate form of placing restrictions on the weights as they simply restrict them to vary within a specific range. Assurance region of type I, link either only input weights (b_r) or only output weights (b_o). The relationship between input and output weights are termed assurance region of type II. Weights restrictions may be applied directly to the DEA weights or to the product of these weights with the respective input or output level, referred to as virtual input or virtual output. The virtual inputs and outputs can be seen as normalized weights reflecting the extent to which the efficiency rating of a DMU_{qt} understood by a given input or output variable. Restrictions on virtual inputs/virtual outputs assume the form in (62.6), where the proportion of the total virtual output of DMU_p accounted for by output q is restricted to lie in the range$[c_q, d_q]$ and the proportion of the total virtual input of DMU_p accounted for by input r is restricted to lie in the range $[b_r, a_r]$.

$$\begin{cases} c_q \le \frac{g_q h_{pq}}{\sum_{q=1}^{t} g_q h_{pq}} \le d_q, & (q = 1, \cdots, t) \\ b_r \le \frac{h_r v_{pr}}{\sum_{r=1}^{k} h_r v_{pr}} \le a_r, & (r = 1, \cdots, k). \end{cases} \tag{62.6}$$

The range is normally determined to reflect prior views on the relative "importance" of the individual outputs and inputs. Constraints such as (62.7) are DMU specific meaning that the DEA model with such constraints may become computationally expensive. Wong and Beasley [19] suggest some methods for implementing restrictions on virtual values:

1. Method 1: Add the restrictions only in respect of DMU_o being assessed leaving free the relative virtual values of the comparative DMU_t;

2. Method 2: Add the restrictions in respect of all the DMU_t being compared. This is computationally expensive as the constraints added will be of the order of $2n(t+k)$;

3. Method 3: Add the restrictions (62.6) only in relation to the assessed DMU, and add constraints (62.7) with respect to the "average" DMU, which has an average

level of the qth output equal to $\sum_{p=1}^{n} u_{pq}/n$ and has an average level of the rth input equal to $\sum_{p=1}^{n} v_{rp}/n$.

$$\begin{cases} c_q \le \dfrac{g_q \sum_{p=1}^{n} u_{pq}/n}{\sum_{q=1}^{t} g_q \left(\sum_{p=1}^{n} u_{pq}/n\right)} \le d_q, \quad (q = 1, \cdots, t) \\ b_r \le \dfrac{h_r \sum_{p=1}^{n} v_{rp}/n}{\sum_{r=1}^{m} h_r \left(\sum_{p=1}^{n} v_{rp}/n\right)} \le a_r, \qquad (r = 1, \cdots, m). \end{cases} \tag{62.7}$$

Restrictions on the virtual input-output weights represent indirect absolute bounds on the DEA weights of the type shown in (a) in (62.3)–(62.5). The imposition of restrictions on virtual inputs or outputs is sensitive to the model orientation. The multipliers formulation, with the virtual weights restrictions applying to DMU_o (method 1), is as below 2, 3, 4:

$$\begin{cases} e_o = \max \sum_{q=1}^{t} u_{qo} g_q \\ \text{s.t.} \begin{cases} \sum_{r=1}^{k} v_{ro} h_r = 1 \\ \sum_{r=1}^{k} v_{pr} h_r - \sum_{q=1}^{t} u_{pq} g_q \ge 0, \ \ \forall \ \ p \\ b_r \left(\sum_{r=1}^{m} v_{ro} h_r \right) - v_{ro} h_r \le 0 \\ v_{ro} h_r - b_r \left(\sum_{r=1}^{m} v_{ro} h_r \right) \le 0 \\ h_r \ge \varsigma \ \forall \ r, g_q \ge \varsigma \ \forall \ q. \end{cases} \end{cases} \tag{62.8}$$

In summary, Model (62.8) proposes a method for selecting the best suppliers in the presence of weight restrictions. Now, to consider dual-role factors and weight restrictions, a new model is proposed. Consider a situation where members p of a set of n DMU_t are to be evaluated in terms of t outputs $u_p = (u_{pq})_{q=1}^{t}$ and m inputs $v_p = (v_{rp})_{r=1}^{m}$. In addition, assume that a particular factor is held by each DMU in the amount Z_p, and serves as both an input and output factor. The proposed model for considering single dual-role factor is as follows [7].

$$\begin{cases} \max \dfrac{\sum_{q=1}^{t} g_q u_{qo} + \Theta Z_o - \Upsilon Z_o}{\sum_{r=1}^{m} h_r v_{ro}} \\ \text{s.t.} \begin{cases} \sum_{q=1}^{t} g_q u_{pq} + \Theta Z_p - \Upsilon Z_p - \sum_{r=1}^{m} h_r u_{rp} \le 0, \ (p = 1, \cdots, n) \\ g_q, h_r, \Theta, \Upsilon \ge 0. \end{cases} \end{cases} \tag{62.9}$$

At this point, to demonstrate how to consider multiple dual-role factors in the model, the following new model is presented. Assume that some factors are held by each

DMU in the amount $Z_{fp}(f = 1, \cdots, F)$, and serve as both an input and output factors. The proposed model for considering multiple dual-role factors is as follows:

$$\begin{cases} \max \dfrac{\sum_{q=1}^{t} g_q u_{qo} + \sum_{f=1}^{F} \Theta_f Z_{fo} - \sum_{f=1}^{F} \Upsilon_f Z_{fo}}{\sum_{r=1}^{k} h_r v_{ro}} \\ \text{s.t.} \begin{cases} \sum\limits_{q=1}^{t} g_q u_{pq} + \sum\limits_{f=1}^{F} \Theta_f Z_{fp} - \sum\limits_{f=1}^{F} \Upsilon_f Z_{fp} - \sum\limits_{r=1}^{k} h_r v_{pr} \le 0, \quad (p = 1, \cdots, n) \\ g_q, h_r, \Theta, \Upsilon \ge 0. \end{cases} \end{cases}$$

The linear programming form of the above Model is as follows:

$$\begin{cases} \max \sum\limits_{q=1}^{t} g_q u_{qo} + \sum\limits_{f=1}^{F} \Theta_f Z_{fo} - \sum\limits_{f=1}^{F} \Upsilon_f Z_{fo} \\ \text{s.t.} \begin{cases} \sum_{r=1}^{k} h_r v_{ro} = 1 \\ \sum\limits_{q=1}^{t} g_q u_{pq} + \sum\limits_{f=1}^{F} \Theta_f Z_{fp} - \sum\limits_{f=1}^{F} \Upsilon_f Z_{fp} - \sum\limits_{r=1}^{k} h_r v_{pr} \le 0, \quad (p = 1, \cdots, n) \\ g_q, h_r, \Theta, \Upsilon \ge 0. \end{cases} \end{cases}$$

At this stage, the model that considers both dual-role factors and weight restrictions is introduced.

$$\begin{cases} \max \sum\limits_{q=1}^{t} g_q u_{qo} + \sum\limits_{f=1}^{F} \Theta_f Z_{fo} - \sum\limits_{f=1}^{F} \Upsilon_f Z_{fo} \\ \text{s.t.} \begin{cases} \sum\limits_{r=1}^{k} h_r v_{ro} = 1 \\ \sum\limits_{q=1}^{t} g_q u_{pq} + \sum\limits_{f=1}^{F} \Theta_f Z_{fp} - \sum\limits_{f=1}^{F} \Upsilon_f Z_{fp} - \sum\limits_{r=1}^{k} h_r v_{pr} \le 0, \quad (p = 1, \cdots, n) \\ g_q, h_r, \Theta, \Upsilon \ge 0 \\ b_r \left(\sum\limits_{r=1}^{m} v_{ro} h_r \right) - v_{ro} h_r \le 0 \\ v_{ro} h_r - b_r \left(\sum\limits_{r=1}^{m} v_{ro} h_r \right) \le 0 \\ h_r \ge \varsigma \; \forall \, r, g_q \ge \varsigma \; \forall \, q, \Theta, \Upsilon \ge 0. \end{cases} \end{cases} \tag{62.10}$$

Therefore, one unified approach that deals with weight restrictions and dual-role factors in a direct manner have been introduced.

Table 62.1 Efficiency scores in the presence of virtual weight restriction and dual-role factor, and input/output behavior [15]

Supplier no.	Efficiency[a]	$\hat{\Theta}_1$	$\hat{\Upsilon}_1$	$\hat{\Theta}_1 - \hat{\Upsilon}_1$
1	0.934	0.002354147	0	0.002354147
2	0.9695	0.002213107	0	0.002213107
3	1	0.002267565	0	0.002267565
4	1	0.003359652	0	0.003359652
5	0.9705	0.00228148	0	0.00228148
6	1	0.007130057	0	0.007130057
7	1	0	0.9176708	−0.9176708
8	0.8842	0.001762005	0	0.001762005
9	0.8859	0.001780101	0	0.001780101
10	0.7653	0.001767251	0	0.001767251
11	0.7628	0.001824056	0	0.001824056
12	0.9053	0.003981494	0	0.003981494
13	0.9228	0.005004239	0	0.005004239
14	0.9132	0.001989893	0	0.001989893
15	0.9775	0.00466217	0	0.00466217
16	0.8169	0.0017675	0	0.0017675
17	1	0.019386	0	0.019386
18	1	0.005784615	0	0.005784615

[a] Efficiency score in the presence of virtual weight restriction and dual-role factor [applying Model (62.10)]

62.3 Numerical Example

The data set for this example is partially taken from Talluri and Baker [16] and contains specifications on 18 suppliers. The supplier inputs considered are Total Cost of shipments (TC), 5 Number of Shipments per month (NS), and Research and Development cost (R&D). The outputs utilized in the study are Number of shipments to arrive On Time (NOT), Number of Bills received from the supplier without errors (NB), and R&D. R&D plays the role of both input and output. According to the decision of decision maker, the importance of TC, as expressed by the weight , must be as follows (method 1): $0.5 \leq \frac{h_r v_{1o}}{\sum_{r=1}^{m} h_r v_{ro}} \leq 3$.

Table 62.1 reports the results of efficiency assessments in the presence of virtual weight restriction and dual-role factor and their input/output behavior for the 18 suppliers obtained by using Model (62.10). ς has been set to be 0.0001. Model (62.10) identified suppliers 3, 4, 6, 7, 17, and 18 to be efficient with a relative efficiency score of 1. The remaining 12 suppliers with relative efficiency scores of less than 1 are considered to be inefficient. Therefore, decision maker can choose one or more of these efficient suppliers. The supplier 7 is the DMU that R&D is behaving like an input.

Using T the null hypothesis that the two groups have the same population at a level of significance a can be checked. In this example, there is $T = 1.0757$. If

$a = 0.05(5\ \%)$ is chosen, then it holds that $T0.025 = 1.96$. Since $T = 1.0757 < 1.96 = T0.025$, the null hypothesis at the significance level 5 % is not rejected. Consequently, the differences among the efficiency scores obtained by Model (62.2) and efficiency scores obtained by Model (62.10) are not statistically significant.

62.4 Conclusions

Strong competitive pressure forces many organizations to provide their products and services to customers faster, cheaper and better than the competitors. Managers have come to realize that they cannot do it alone without satisfactory suppliers. Therefore, the increasing importance of supplier selection decisions is forcing organizations to rethink their purchasing and evaluation strategies and hence the selection of suppliers has received considerable attention in the purchasing literature.

This paper has provided a model for selecting suppliers in the presence of dual-role factors and weight restriction. Notice that, whatever we propose any possible process to improve DEA model, there always is a result that shows the best DMU_t as efficient so that their efficiency scores equal to one. The reason is that DEA measures the relative efficiency of DMU_t. As well, there are too many DEA models. Each DEA model has a specific assumption which should be considered beforehand. In real world, decision makers should take into consideration these assumptions. As a result, the proposed model is only a possible way to achieve better supplier selection but not sufficient. In other words, the proposed model assumes that weight restrictions and dual-role factors are present. It is obvious that if these assumptions are not applicable, the proposed model can not be used.

The problem considered in this study is at initial stage of investigation and many further researches can be done based on the results of this paper. Some of them are as follow:

1. Similar research can be repeated for dealing with fuzzy data in the conditions that dual-role factors exist.
2. One of the limitations of this paper is that the proposed model assumes all suppliers are completely homogeneous. As Saen [13] discussed, the assumption of classical supplier selection models is based on the principle that suppliers consume common inputs to supply common outputs. In spite of this assumption in many applications some suppliers do not comprehensively consume common inputs to comprehensively supply common outputs. In other words, different industrial suppliers may have many differences between them. To evaluate the relative efficiency of suppliers, all the suppliers may not have identical functions. It is clear that zero value allocation for this type of input, causes relative efficiency of the supplier, to increase unrealistically.

Generally, zero allocation to outputs and inputs of some suppliers, makes the efficiency evaluation unfair. That is zero allocation to output, may make a supplier inefficient, on the other hand, zero allocation to input, and may make a supplier efficient, unrealistically. Saen [14] proposes a model for selecting slightly non-homogeneous suppliers. However, he did not consider weight restrictions and dual-role factors. A potential extension to the methodology includes the case that some of the suppliers are slightly non-homogeneous in the presence of both weight restrictions and dual-role factors.

This study used the proposed model for supplier selection. It seems that more fields (e.g. technology selection, personnel selection, etc.) can be applied.

Acknowledgments The authors wish to thank the anonymous referees for their helpful and constructive comments and suggestions. 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).

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Chapter 63
Multiobjective Decision-Making Model in Cold Chain Logistics Inventory System Under Complex Random Phenomenon

Can Ding and Yunqiang Liu

Abstract This paper focuses on inventory management in cold chain logistics problem. Based on the analysis of the overlapped randomness, the multi-objective expected value model with random–random variables is formulated to deal with decision makers' preferences. A random simulation-based PSO algorithm for solving the programming is developed to tackle objective functions and constraints. The proposed model and algorithm are applied to inventory optimization of cold chain logistics problem. The results illustrate the effectiveness of the proposed model and algorithm, and contrastive analysis of parameters shows the proposed algorithm has good robustness towards key parameters.

Keywords Inventory management · Random–random variable · Multiobjective programming · PSO

63.1 Introduction

Inventory management is a key process of supply chain management. Inventory management is one of the important cause of the high cost of retail enterprises in logistics system, and also is directly related to product quality and safety. Effective inventory control is one of the main effective means to increase revenues and reduce total spending of the logistics system. The study of inventory control theory is from the problem of banks to determine keeping how much cash flow in the early twentieth century [8, 11]. From the Economic Order Quantity (EOQ) Model is proposed by

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_63,

Harris in 1915, a large number of scholars has explored this model, and produced many research results [2, 7]. Inventory control is always a hot area of research of management science, operational research [1, 6].

In fact, the inventory problem is widespread, it can be divided into certainty and uncertainty problems, also can be divided into static and dynamic inventory problems [13]. Inventory control problem needs to consider multiple objectives, so the objective function is complex. On the other hand, the objective function is to maximize the probability of target profit, utility, or multiple objectives, which is different from traditional forms. So due to the special requirements and local conditions, the variables often contain some uncertain factors, and these objectives and parameters are usually inaccurate.

Randomness is one important source of uncertainty in actual analysis. However, logistics network design problems may be subject to some type of complex randomness with incomplete or uncertain information. This randomness can be called overlapped randomness in the paper, which will be introduced in Sect. 63.2. Therefore, the paper proposes a view and method of modelling inventory in the real environment for selection, so as to optimize inventory levels in the logistics system.

The rest of this paper is organized as follows. Section 63.2 states the overlapped randomness in the inventory problem, and makes some assumptions for the problem. Section 63.3 proposes the multi-objective expected value model with Ra–Ra coefficients. The Ra–Ra-EVS-based PSO algorithm is presented to handle the objective functions and constraints for solving the model in Sect. 63.4. In Sect. 63.5, a case study is provided to illustrate the application of the proposed model and algorithm. Finally concluding remarks are outlined in Sect. 63.6.

63.2 Problem Statement

This paper will study the inventory control problem in cold chain logistics which represented by fresh agricultural products. It is a inventory problem of multi-product, infinite replenishment rate, no shortage, inventory depends on demand, effective budget and inventory space, as shown in Fig. 63.1. In this system, due to the influence of various uncertain factors, assume the products demand, products price, purchase price, order cost and create cost as complex random variables, the budget and inventory space as constant.

The inventory control problem in cold chain logistics, is much complex, and exists uncertainty. To model for this inventory problem with the complex random phenomena, a few assumptions are summarized as follows.

- There are only one supplier and one customer in the system, the supplier provides multi products, and the customer has a demand for many kinds of products.
- Regardless of shortage, the inventory can instantly get added when storage reduces to zero.

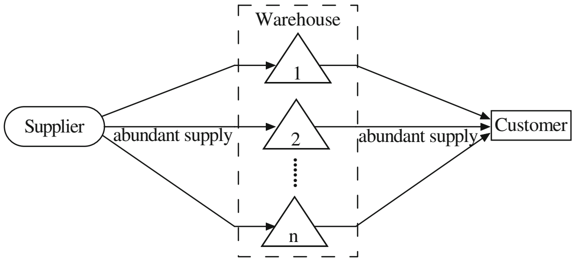

Fig. 63.1 The inventory control system in this study

- All uncertain parameters in the problem are supposed to be complex random variables.
- The original sale price of the products are higher than the cost, which shows sales are profitable.

Considering this pattern of complex randomness, we define this kind of variables as random–random (Ra–Ra) variables. In probability and statistics, a random variable or stochastic variable is a real-valued function defined over a sample space [9]. The mathematical definition of Ra–Ra variables is given as follows,

Definition 63.1 Let $\tilde{\mu}$ be a random variable on the probability space $(\Omega', \mathscr{A}', Pr)$. It is said ξ to be a Ra–Ra variable with respect to $\tilde{\mu}$ on probability space $(\Omega, \mathscr{A}, Pr)$, if and only if $\forall\, \omega \in \Omega$, $\xi(\omega)$ is a random variable with the density function $\bar{p}(x, \tilde{\mu}(\omega'))$, i.e.,

$$\bar{F}(x) \equiv: Pr\{-\infty \le \xi(\omega) \le x\} = \int_{-\infty}^{x} \bar{p}(y, \tilde{\mu}(\omega'))dy,$$

where the function $\bar{p}(x, \tilde{\mu}(\omega'))$ satisfies $\bar{p}(x, \tilde{\mu}(\omega')) \ge 0$ and $\int_{-\infty}^{+\infty} \bar{p}(x, \tilde{\mu}(\omega'))dx = 1$, for $\forall\, \omega' \in \Omega'$.

Lemma 63.1 [14] *Let $\tilde{\tilde{\xi}}$ be a Ra–Ra variable defined on the probability space $(\Omega, \mathscr{A}, Pr)$, if the expected value $E[\tilde{\xi}(\omega)]$ of random variable $\tilde{\xi}(\omega)$ is finite for any $\omega \in \Omega$, then $E[\tilde{\xi}(\omega)]$ is a random variable defined on the probability space.*

Definition 63.2 [14] Let $\tilde{\tilde{\xi}}$ be a Ra–Ra variable defined on the probability space $(\Omega, \mathscr{A}, Pr)$, Then the expected value of Ra–Ra variable $\tilde{\tilde{\xi}}$ is defined as:

$$E[\tilde{\tilde{\xi}}] = \int_{0}^{+\infty} Pr\{\omega \in \Omega | E[\tilde{\xi}(\omega)] \ge t\}dt - \int_{-\infty}^{0} Pr\{\omega \in \Omega | E[\tilde{\xi}(\omega)] \le t\}dt, \quad (63.1)$$

provided that at least one of the above two integrals is finite.

63.3 Modelling

In this section, we will give the mathematical notations at first, and then propose a multi-objective expected value programming for the problem.

63.3.1 Notation

The mathematical notations are as follows.
Index

i The index of products, $i = 1, 2, \cdots, n$.

Parameters

A_i	The storage space of unit ith product
A	The total storage space can be used
B	The total budget can be used
T_i	The sales cycle of ith product
$\tilde{\tilde{D}}_i$	The demand of ith product in unit sales cycle
$\tilde{\tilde{K}}_i$	The order cost of ith product
H_i	The average holding cost of ith product in each sales cycle
$\tilde{\tilde{h}}_i$	The holding cost of ith product in unit time
$\tilde{\tilde{p}}_i$	The selling price of unit ith product
$\tilde{\tilde{c}}_i$	The purchasing price of unit ith product
$\tilde{\tilde{s}}_i$	The create cost of unit ith product in unit cycle
b_i	The rotting rate of ith product, $0 < b_i < 1$
TC	The average total cost of ith product
TP	The average total profit of ith product
TW	The average total loss cost of ith product.

Decision variables

Q_i The sales volume of ith product, that is, customer order.

63.3.2 Model Formulation

In the inventory management system, there are three related data: demand volume $\tilde{\tilde{D}}_i$, order cost $\tilde{\tilde{K}}_i$, and holding cost of unit product $H_i(t) = \tilde{\tilde{h}}_i t^{\alpha_i}$, which increases along with time, where $\alpha_i > 1$ is a constant.

For product i, the order quantity is Q_i, and the demand quantity is $\tilde{\tilde{D}}_i$, so its order cycle is $T_i = Qi/\tilde{\tilde{D}}_i$.

In the first order cycle $[0, T]$, the total holding cost of all products is $\tilde{\tilde{h}}_i t^{\alpha_i} = \int_0^{T_i} \alpha_i \tilde{\tilde{h}}_i x^{\alpha_i - 1} dx$.

In one order cycle, the inventory changes along with time t, $I(t) = Q_i - \tilde{\tilde{D}}_i t$, so in the cycle $[0, T]$, the average holding cost of product i is:

$$Hi = \frac{1}{T_i} \int_0^{T_i} I(t) \alpha_i \tilde{\tilde{h}}_i x^{\alpha_i - 1} dx = \frac{1}{T_i} \int_0^{T_i} Q_i - \tilde{\tilde{D}}_i x \alpha_i \tilde{\tilde{h}}_i x^{\alpha_i - 1} dx = \frac{\tilde{\tilde{h}}_i Q_i^{\alpha_i}}{(\alpha_i + 1) \tilde{\tilde{D}}_i^{\alpha_i - 1}}. \tag{63.2}$$

Therefore, Eq. (63.2) is an average holding cost in finite time. The total inventory cost in the cycle is the sum of holding cost, order cost, and create cost, so the total inventory cost of product i is:

$$TC = \frac{\tilde{\tilde{h}}_i Q_i^{\alpha_i}}{(\alpha_i + 1) \tilde{\tilde{D}}_i^{\alpha_i - 1}} + \tilde{\tilde{K}}_i + \tilde{\tilde{s}}_i. \tag{63.3}$$

From Eq. (63.2), the total loss of product i is:

$$W_i = \frac{b_i Q_i^{\alpha_i}}{(\alpha_i + 1) \tilde{\tilde{D}}_i^{\alpha_i - 1}}.$$

The net revenue of product i is: $R_i = (p_i - c_i) Q_i - p_i W_i$.

In the inventory system, the objectives of decision makers are to maximize the total profit, and minimize total loss cost. The total profit of products in one cycle is: $TP = R - TC$.

The total loss cost is: $TW = \tilde{\tilde{c}}_i W_i$.

There are two constraints of the inventory decision model, one is budget constraint, that is, the total cost must be kept in the budget: $\sum_{i=1}^{n} TC \leq B$. The other one is the constraint of warehouse storage space, that is, the total storage volume of all products cannot exceed the total storage space $\sum_{i=1}^{n} A_i Q_i \leq A$.

According to the assumption, the uncertain variables in the system are all Ra–Ra variables. Influenced by the uncertainty, TC, R_i, W_i are all uncertain variables. Based on the analysis above, the multi-objective, multi-product inventory optimization model is built as follows:

$$\begin{aligned} &\max TP = \tilde{\tilde{R}} - \widetilde{\widetilde{TC}} \\ &\min TW = \tilde{\tilde{c}}_i \tilde{\tilde{W}}_i \\ &\text{s.t.} \begin{cases} \sum_{i=1}^{n} \widetilde{\widetilde{TC}} \leq B \\ \sum_{i=1}^{n} A_i Q_i \leq A \\ Q_i \geq 0, \quad i = 1, 2, \cdots, n. \end{cases} \end{aligned} \tag{63.4}$$

For product i, if the create cost $\tilde{\tilde{s}}_i$ in cycle $[0, T]$ is not considered, then the average inventory cost is

$$TC' = \frac{\tilde{\tilde{h}}_i Q_i^{\alpha_i}}{(\alpha_i + 1)\tilde{\tilde{D}}_i^{\alpha_i - 1}} + \frac{\tilde{\tilde{D}}_i}{Q_i}\tilde{\tilde{K}}_i. \tag{63.5}$$

In most cases, it is hard to determine if (63.5) is a convex function. Through the first order condition, the optimal order quantity Q^* can obtain from the following equation

$$Q_i^* = \sqrt[\alpha_i+1]{(1 + 1/\alpha_i)\frac{\tilde{\tilde{K}}_i \tilde{\tilde{D}}_i^{\alpha_i}}{\tilde{\tilde{h}}_i}}. \tag{63.6}$$

If ignore the uncertainty, and $\alpha_i = 1$, we can get the classical EOQ Model $Q_i^* = \sqrt{\frac{2K_i D_i}{h_i}}$.

In inventory decision-making, when the parameters and other information change indefinitely, the decision makers always hope to maximize or minimize the expected value of the objective function. For this purpose, according to the definition of expected value of complex random variables [14], decision makers usually consider maximum profit and minimum cost in the average level, then the model (63.4) can be transformed equivalently as follows

$$\begin{array}{l} \max TP = E\left[\tilde{\tilde{R}} - \widetilde{\widetilde{TC}}\right] \\ \min TW = E\left[\tilde{\tilde{c}}_i \tilde{\tilde{W}}_i\right] \\ \text{s.t.} \begin{cases} E\left[\sum\limits_{i=1}^{n} \widetilde{\widetilde{TC}}\right] \le B \\ E\left[\sum\limits_{i=1}^{n} A_i Q_i\right] \le A \\ Q_i \ge 0, \quad i = 1, 2, \cdots, n. \end{cases} \end{array} \tag{63.7}$$

63.4 Ra–Ra-EVS-Based PSO

Traditional method of solving this uncertain programming (63.7) is to convert the objective functions and constraints to their respective deterministic equivalents. However, this process is usually quite difficult. In this section, we will introduce the technique of Ra–Ra simulation, and it will be embed into particle swarm optimal algorithm to form a Ra–Ra-EVS-based PSO algorithm to solve this problem.

63.4.1 Ra–Ra Simulation for EV

Ra–Ra simulation for expected value (EV) is represented as Ra–Ra-EVS. Considering to calculate the expected value $E[f(\xi)]$, for the given ξ on the probability space $(\Omega, \mathscr{A}, Pr)$. When $f(\xi)$ is complicated, we may calculate the expected value $E[f(\xi)]$ by random simulation. For each ω, $f(\xi(\omega))$ is a random variable, and $E[f(\xi(\omega))]$ can be calculated by random simulation. Calculating $E[f(\xi)]$ is calculating $E[f(\xi(\omega))]$ in fact, so expected value simulation of a random–random variable can form through nesting random–random simulation by the following process.

Firstly, we sample $\omega_i^1, \omega_i^2, \cdots, \omega_i^M$ from Ω according to Pr, where ω_k is an n-dimensional vector. For each $\omega_i (i = 1, 2, \cdots, N)$, $\boldsymbol{\xi}(\omega_i)$ are all random variables. Compute $f(\boldsymbol{x}, \boldsymbol{\xi}(\omega_i^1))$, $f(\boldsymbol{x}, \boldsymbol{\xi}(\omega_i^2)), \cdots, f(\boldsymbol{x}, \boldsymbol{\xi}(\omega_i^M))$. Then

$$E[f(\boldsymbol{x}, \boldsymbol{\xi}(\omega_i))] = \frac{\sum_{j=1}^{M} f(\boldsymbol{x}, \boldsymbol{\xi}(\omega_i^j))}{M}.$$

Next, we can get the expected value of $f(\boldsymbol{x}, \boldsymbol{\xi})$ as follows,

$$E[f(\boldsymbol{x}, \boldsymbol{\xi})] = \frac{\sum_{i=1}^{N} E[f(\boldsymbol{x}, \boldsymbol{\xi}(\omega_i))]}{N}.$$

63.4.2 Ra–Ra-EVS-PSO

PSO was proposed by Kennedy and Eberhart [5] and is one of the latest evolutionary optimization techniques for optimizing continuous nonlinear functions. PSO incorporates swarming behaviors observed in flocks of birds, schools of fish, or swarms of bees, and even human social behavior, from which the idea is emerged [3, 10]. As an algorithm, the main strength of PSO is its fast convergence, which compares favorably with many global optimization algorithms like Genetic Algorithms (GA) [4], Simulated Annealing (SA) [12] and other global optimization algorithms.

The notation used in the algorithm is given as follows.

t	Iteration index, $t = 1, \cdots, T$
l	Particle index, $l = 1, \cdots, L$
r_1, r_2	Uniform random number in the interval [0, 1]
w	Inertia weight
h	Dimension index, $h = 1, 2, \cdots, H$
c_p	Personal best position acceleration constant
c_g	Global best position acceleration constant
p_h^l	Position of the lth particle at the hth dimension
v_h^l	Velocity of the lth particle at the hth dimension
$p_h^{l,best}$	Personal best position of lth particle at the hth dimension

$g_h^{l,best}$	Global best position at the hth dimension
P^l	Vector position of the lth particle, $P^l = (p_1^l, p_2^l, \cdots, p_H^l)$
V^l	Vector velocity of the lth particle, $V^l = (v_1^l, v_2^l, \cdots, v_H^l)$
$\Theta^{l,best}$	Vector personal best position of the lth particle $\Theta^{l,best} = (p_1^{l,best}, p_2^{l,best}, \cdots, p_H^{l,best})$
$\Psi^{l,best}$	Vector global best position $\Psi^{l,best} = (g_1^{l,best}, g_2^{l,best}, \cdots, g_H^{l,best})$
$Fit(P^l)$	Fitness value of P^l.

For the model (63.7), the procedure of Ra–Ra-EVS-PSO algorithm can be summarized as follows.

Step 1. Transform the multi-objective $\min_{\boldsymbol{x}} \sum_{i=1}^m \lambda_i E[F_i(x, \tilde{\tilde{\xi}})]$, and use Ra–Ra-EVS to deal with the Ra–Ra variables in the model (63.7).
Step 2. Generate vector position P^l, vector velocity V^l, $l = 1, 2, \cdots, L$.
Step 3. Let $t = 1$, initial the particle.
Step 4. For the lth particle, use the fitness value $Fit(P^l) = \sum_{i=1}^m \lambda_i F_i(P^l, E[\tilde{\tilde{\xi}}])$ to evaluate the lth particle, and obtain personal best position $p_h^{l,best}$ and global best position $g_h^{l,best}$.
Step 5. Let $t = t + 1$. Update the current position and velocity according to the following rules

$$v_h^l(t_l + 1) = \omega_l(t_l)v_h^l(t_l) + c_p r_1[p_h^{l,best} - p_h^l(t_l)]c_g r_2[g_h^{l,best} - p_h^l(t_l)], \tag{63.8}$$

$$p_h^l(t_l + 1) = p_h^l(t_l) + v_h^l(t_l + 1). \tag{63.9}$$

Step 6. Use the fitness value $Fit(P^l)$ to evaluate the lth new particle, and obtain new personal best position $p_h^{l,best}$ and global best position $g_h^{l,best}$.
Step 7. If $t_l = T_l$, then turn to Step 7, or else, turn to Step 4.
Step 8. Export global best position $\Psi^{l,best}$ as the optimal solution of the model.

63.5 Case Study

In this section, a case study is given to show the application of the proposed model and algorithm. The problem considered in this case is from a fruit sales company, Company F, which is founded in 2003. The company is a large-scale agricultural enterprise, including fruit planting, purchasing, processing, cold storage, transporting, wholesaling, distributing, and import and export trade.

63.5.1 Optimal Solution

In the inventory management system, there are two types of products ($n = 2$), and the demand volume values are all Ra–Ra variables: $\tilde{\tilde{D}}_1 \sim \mathcal{N}(\tilde{\mu}_1, 25)$, $\tilde{\mu}_1 \sim$

Table 63.1 The determined parameters

Product	b_i	A_i	α_i
$i = 1$	0.03	0.5	2.1
$i = 2$	0.04	0.6	2.4

Table 63.2 The Ra–Ra variables

Product	$\tilde{\tilde{K}}_i$	$\tilde{\tilde{p}}_i$	$\tilde{\tilde{c}}_i$	$\tilde{\tilde{s}}_i$	$\tilde{\tilde{h}}_i$
$i = 1$	$\tilde{\omega}_1(6)$	$\tilde{\omega}_3(2)$	$\tilde{\omega}_5(0.2)$	$\tilde{\omega}_7(16)$	$\tilde{\omega}_9(0.06)$
$i = 2$	$\tilde{\omega}_2(4)$	$\tilde{\omega}_4(3)$	$\tilde{\omega}_6(0.3)$	$\tilde{\omega}_8(20)$	$\tilde{\omega}_{10}(0.06)$

Table 63.3 The optimal inventory strategies

Q_1	Q_1	R	TC	TW	TP
241.47	267.38	2,014.18	648.10	53.55	1,648.39

$\mathscr{N}(150, 12)$; $\tilde{\tilde{D}}_2 \sim \mathscr{N}(\tilde{\mu}_2, 30)$, $\tilde{\mu}_2 \sim \mathscr{N}(200, 25)$. Assume $A = 300$, $B = 3{,}500$ (Yuan RMB), the other data are shown in Tables 63.1 and 63.2.

Table 63.1 gives the values of the parameters in the model. The data given in Table 63.2 is means (standard deviation). $\tilde{\tilde{K}}_i$, $\tilde{\tilde{p}}_i$, $\tilde{\tilde{c}}_i$, $\tilde{\tilde{s}}_i$, $\tilde{\tilde{h}}_i$ normally distributed, $\tilde{\omega}_j$ $(j = 1, 2, \cdots, 10)$ are random variables defined as follows,

$$\begin{array}{llll} \tilde{\omega}_1 \sim \mathscr{U}[20, 30], & \tilde{\omega}_2 \sim \mathscr{U}[25, 35], & \tilde{\omega}_3 \sim \mathscr{N}(8, 1.5), & \tilde{\omega}_4 \sim \mathscr{N}(9, 2.5), \\ \tilde{\omega}_5 \sim \mathscr{N}(4, 0.9), & \tilde{\omega}_6 \sim \mathscr{N}[4.5, 0.8], & \tilde{\omega}_7 \sim \mathscr{U}[125, 155], & \tilde{\omega}_8 \sim \mathscr{U}[135, 155], \\ \tilde{\omega}_9 \sim \mathscr{U}[0.9, 1.1], & \tilde{\omega}_{10} \sim \mathscr{U}[0.9, 1.1]. & & \end{array}$$

Take all the values into the model (63.7), use the Ra–Ra-EVS-based PSO algorithm proposed in Sect. 63.4 to solve the problem, where simulation times is 300, the PSO iteration index is 300, the scale of initial particle is 20, the accelerated factor is 2, and the inertia weight is 0.5. Through calculating, we obtained the optimal inventory decision strategies as shown in Table 63.3.

63.5.2 Contrastive Analysis

In inventory optimal control problem, the demand is the biggest factor which influences the optimal inventory strategy. To study how the demand influence the inventory strategy, we compare the optimal inventory strategies under different parameters.

For product 1, $\tilde{\tilde{D}}_1 \sim \mathscr{N}(\tilde{\mu}_1, \sigma_1^2)$, where $\tilde{\mu}_1 \sim \mathscr{N}(150, \sigma_{11}^2)$, which can be divided into four situations $\sigma_1^2 = 20$, $\sigma_1^2 = 15$, $\sigma_1^2 = 10$, $\sigma_1^2 = 5$. For product 2, $\tilde{\tilde{D}}_2 \sim \mathscr{N}(\tilde{\mu}_2, \sigma_2^2)$, where $\tilde{\mu}_2 \sim \mathscr{N}(200, \sigma_{21}^2)$, which can be divided into the following four situations $\sigma_1^2 = 25$, $\sigma_1^2 = 15$, $\sigma_1^2 = 10$, $\sigma_1^2 = 5$. For σ_{11}^2 and σ_{21}^2,

Table 63.4 The level with $\sigma_1^2 = 20$

Variance	Q_1	Q_2	TW	TP
$\sigma_2^2 = 25$	227.79	299.98	44.58	1,602.41
$\sigma_2^2 = 15$	233.72	331.93	51.97	1,674.34
$\sigma_2^2 = 10$	247.99	371.54	62.89	1,806.69
$\sigma_2^2 = 5$	280.40	423.74	84.95	1,991.00

Table 63.5 The level with $\sigma_1^2 = 15$

Variance	Q_1	Q_2	TW	TP
$\sigma_2^2 = 25$	260.15	297.81	55.56	1,649.59
$\sigma_2^2 = 15$	265.84	330.37	64.12	1,751.90
$\sigma_2^2 = 10$	280.24	371.35	73.69	1,885.14
$\sigma_2^2 = 5$	348.89	375.93	81.58	2,040.60

Table 63.6 The level with $\sigma_1^2 = 10$

Variance	Q_1	Q_2	TW	TP
$\sigma_2^2 = 25$	303.37	300.29	62.09	1,757.40
$\sigma_2^2 = 15$	309.37	333.54	70.12	1,859.86
$\sigma_2^2 = 10$	324.54	376.14	76.86	1,993.10
$\sigma_2^2 = 5$	356.33	369.73	81.25	2,040.66

Table 63.7 The level with $\sigma_1^2 = 5$

Variance	Q_1	Q_2	TW	TP
$\sigma_2^2 = 25$	366.53	315.06	73.82	1,923.38
$\sigma_2^2 = 15$	374.13	349.57	79.31	2,025.19
$\sigma_2^2 = 10$	356.33	369.73	81.25	2,040.66
$\sigma_2^2 = 5$	356.33	369.73	81.25	2,040.66

it can also be divided into several situations to analyze. By using the model and algorithm, the optimal inventory strategies under different situations are shown in Tables 63.4, 63.5, 63.6, 63.7.

From Tables 63.4, 63.5, 63.6, 63.7, the total profit and total loss cost decrease along with variance, and the variation of total profit under low variance is less than under high variance, the maximal value is 2,040.66. The total loss cost has similarly variation trend.

For the PSO algorithm proposed in this paper, change the key parameters, such as iteration index, inertia weight and acceleration factor, to calculate the optimal results under different parameters, as shown in Table 63.8.

Table 63.8 The results under different parameters

Iteration index	Population size	Inertia weight	Acceleration factor	TW	TP
300	10	0.3	1	58.09	1,757.40
300	10	0.3	2	65.31	1,872.19
300	20	0.5	3	78.68	2,026.84
500	20	0.5	2	81.17	2,039.38
500	30	0.7	3	81.25	2,040.66
1,000	30	0.7	3	81.25	2,040.66
1,000	40	0.7	5	81.25	2,040.66

It can be seen that, when the iteration index exceeds 500, no matter how to adjust parameters, the objective function value has little variation, which indicates that the solution space has converged to a narrow sphere. Generally speaking, the proposed algorithm has good robustness towards key parameters, such as iteration index, population size, inertia weight, and acceleration factor.

63.6 Conclusion

This paper has presented a multi-objective programming with random–random coefficients for multi-product inventory control problem in cold chain logistics system. We assume the demand, the selling price, purchasing price, the order cost and create cost to be random–random variables. In the model, we consider the two objectives handling decision maker's average expected level of his decision making. In order to solve the model, the random–random simulation for expected value based PSO algorithm is proposed, and its feasibility is proved through a case study. The optimal results under different parameters are calculated for comparison. Further work can concentrate on more practical problems related to engineering and management and other new resolve approaches.

Acknowledgments This research has been supported by the Key Scientific Research Projects of Xihua University, P.R. China (Grant No. Z1321501).

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Chapter 64
Process-Based Supply Chain Performance Measurement

Hua Wen

Abstract Performance measurement is important to improve organizational competitiveness. Organizations and researchers have developed and investigated various performance-measurement systems to manage and improve internal and external operations for logistics and supply chain (SC). Supply chain management (SCM) refers to all of the processes, technologies, and strategies, and the many-factored elements interact each other, so the performance measurement approach of supply chain is a difficult proposition. In traditional SC performance assessment approach, the SC metrics are difficult to define and to measure, and this kind of assessment focuses more on financial data and outcomes. Process-based SC performance assessment supports a process-oriented view, and gives early warning signals. This paper describes the common SC performance measurement approaches and the process-based SC performance measurement approaches in detail, and aims at revealing different kind of approaches of performance measurement in the new supply chain era.

Keywords Supply chain management · Performance measurement · Process-based measurement

64.1 Introduction

In recent years, business organizations are increasingly finding it necessary to be extremely flexible in responding to changes in the market environment, manufacturing, distribution, and retailing have made significant performance improvement by adopting the concept of supply chain management (SCM), which is a virtual organization, and are concentrating on supply chain performance rather than their

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_64,

Fig. 64.1 Supply chain single line

organizational performance. As supply chain continue to replace individual companies as the management arena for value-adding to the customers from the beginning of the twenty first century, understanding the supply chain management practices in a more whole context becomes increasingly important.

Many organizational efforts have been undertaken by many modern enterprises, wherein the concept of a process-centered has received a lot of attention. Assessing process performance is essential because it enables individuals and groups to assess where they stand in comparison to their competitors, and prides the opportunity of recognizing problems and taking corrective action before these problems escalate.

In logistics and supply chain, performance measurement and the other three competencies (positioning, integration, and agility) have been considered the four key competencies [21]. Researchers believe that tools for measuring an organization's need and ability are help to develop an agile business strategy within the context of a virtual organization. Good performance measures and metrics are not just measuring the performance, but also embedded with politics, emotions and several other behavioral issues. Holmberg summarized the typical problems in a performance management system (PMS): organization's strategy and measurement system are not connected, and a biased focus on financial metrics, and too many isolated and incompatible measure [11]. There is a need for more representative performance measures and metrics to reflect the performance of new environments.

64.2 Supply Chain Management

One of the definitions of SCM, by the Global Supply Chain Forum (GSCF), is typically described as: "SCM is the integration of key business processes from end user through original suppliers that products, services and information that add value for customer and other stakeholders".

SCM holds a systems perspective in which all the members are functionally integrated and synchronized with mutual goals, which growth and development are attributed to a number of factors such as increasing globalization, reduced barriers to international trade, improvement in information availability, and environmental concerns. The current trend of SCM is to apply information technology to integrate cross-enterprises and inter-enterprise process.

1. Supply Chain (SC)

Supply chain can be defined with a single line diagram as shown Fig. 64.1 [1].

- The flow consists of all parties involved, directly or indirectly, in fulfilling a customer request.

- The flow consists of all the processes involved in converting customer request into customer delight.

How to promote and protect flow smooth, efficiency and effect, few key principles are suggested [19]:

(1) Time is the ultimate constraint. Because of the continual shrinkage of customer tolerance times, it is more important than ever before. The important time is the time through the system;
(2) The system must be well-defined and understood. It contributes to determine whether the existing system is even capable of optimal flow;
(3) Linkages or connections between points in the system must be smooth. Material object and information need to pass smoothly from one point to the other. The more is impeded ,the longer the system cycle time, and the greater the working capital investment.

In 2009, Akyuz and Erkan [2] reviewed 42 articles from major science-cited journals about supply chain and categorized into six main subgroups according to their common themes:

(1) General trends and issues in supply chain;
(2) Dynamic modeling approaches;
(3) Supply chain performance management issues;
(4) Process maturity-supply chain performance relation;
(5) KPI prioritization and dependence;
(6) Human and organizational sides of supply chain performance management.

In the last decade, so many literatures are generated in the field of SCM. However, further attentions and more efforts are required, especially in [20]:

(1) Mapping the supply chain network structure and business processes;
(2) Achieving really seamless integration of supply chain entities and processes; and
(3) Evaluating the performance of the entire supply chain.

2. Supply Chain Integration (SCI)

SCM should be based on holistic system perspective wherein issues beyond the traditional organizational boundaries. The aim of SCM is to globally optimize material and information flows in SC by horizontal integration between companies within SC and vertical integration of existing business processes in each company [10].

According to the Council of Supply Chain Management Professionals (CSCMP), the goal of SCM is the integration of supply and demand management within and across firms [13]. SCI originates from a system perspective where optimization of the whole achieves better performance than a string of optimized sub-systems. SCI is the degree to which firms strategically collaborate with their SC partners and management intra- and inter-organizational processes [8]. SCI scope is defined as a construct with different boundary that bases on ‘arcs of integration’ [9]. It is not sure that SCI scope was positively related to business performance [7].

Three powerful dimensions to SCI are suggested [15]: (1) organizational relationship linkages; (2) information integration; (3) co-ordination and resource sharing. SCI emphasizes the need for internal integration of key functional areas (product development, sourcing, logistics and operations etc.), and the need for upstream integration with first tier suppliers, and downstream integration with customers.

Close co-operation needs to be judiciously considered and depends on business characteristics [22]. Not all relationships should be fully integrated, and effective and important partnerships should be focused [6], so the depth of integration has been subdivided into the strategic, tactical and operational levels [4]. At the tactical level, the integration practices focus around collaborative planning, problem solving and continuous improvement from a position of open information exchange, and at the strategic level, supply chain can lever their separate core competences and achieve system-wide synergy. Suppliers, manufacturers, third-party providers, and customers are encouraged to identify and partner with firms that share a common vision and are pursuing parallel objectives pertaining to partnership interdependence and principles of collaboration. In short, SCI can think and act as one.

64.3 Traditional Supply Chain Performance Assessment Approaches

Supply chain measurement system is required to manage coordinated supply chain operations. These systems must track performance across the borders of internal functional areas and external supply chain partners, and measure the operations of the overall supply chain as well as the financial performance of individual firms. Ultimately, measurement integration requires a comprehensive understanding of all the variables that affect a supply chain's ability to deliver value to the customer.

1. Performance Assessment

In the operations management literature, performance measurement focused on assessment of internal processes, such as machine utilization, machine reliability, employees' productivity, inventory turnover etc. The performance measurement system helps to bring fundamental changes in the relationship between the organization and its employees, customers, suppliers and other stakeholders.

Gunasekaran and Kobu [10] presented the following as the purposes of performance measurement system: (1) identifying; (2) identifying if customer needs are met; (3) better understanding of processes; (4) identifying bottlenecks, waste, problems and improvement opportunities; (5) providing factual decisions; (6) enabling progress; (7) tracking progress; and (8) facilitating a more open and transparent communication and co-operation.

Performance measurement is vital in strategy formulation and communication and in forming diagnostic control mechanisms by measuring actual results. Holmberg identified in-depth problems of PMSs in SC context including [12]: (1) Lack of balanced approach to integrating financial and non-financial measures, (2) Lack of system thinking, because the measurement system for SC should span the entire SC, and (3) Loss of SC context, and hence it is easy to encourage local optimization.

2. Non-financial Performance Measurement

The goal of non-financial performance measurement is to align managerial incentives with long-term shareholder value and to better align shareholder value creation with whole value creation.

According to the above, and combining the characteristics of SC, the afterward assessment method, which means assessing the results only, is inadequate for the performance measurement system for SC.

3. Dimension and KPI of Supply Chain Performance Assessment

With the increasing awareness of the strategic implications of logistics and growing awareness of the benefits of leveraging logistics to increase customer value, measuring the performance of logistics has become a high priority.

For the supply chain, the general processes and structures can be integrated into six core processes that are linked: suppliers, inbound logistics, manufacturing, outbound logistics, marketing and sales, and end customers [20]. The supply chain performance measurement is a difficult proposition because it is affected by, and in turn affects, many aspects of the firm's operations and environment.

Cohen et al. expressed that supply chain metrics are difficult to define and even more difficult to measure. Measurement is the only way to understand whether process performance is improving or worsening and whether action is required [5].

About process-based performance measurements, in terms of quality, effectiveness, efficiency, timeliness, costs, etc. are focused. Beamon extended the traditional concept of performance evaluation to SCM, and categorized it into three aspects: resources, output and flexibility [3].

At the same time, supply chain performance itself is researched and discussed popularly. Three main classes of supply chain performance are discussed: inventory, cycle time and financials [17]. The metrics of supply chain performance are categorized into five classes: order planning, supplier evaluation, production level, delivery and customer.

Ainapur et al. [1] select total 24 KPIs under 5 attributes of SC measurement as Table 64.1.

Many researches explore the relationship between SCM and performance, and integration, collaboration and the information system are the important elements in SCM. The results of explores are very different in definition, measurement, and outcomes [8].

64.4 Process-based Supply Chain Performance Assessment

Traditional performance measurement systems belong to the accounting department. Modern performance measurement system should support a process-oriented view, and companies need a system which fulfils two requirements: first, the measurement system should be focused on processes, not on whole organizations or organizational

Table 64.1 List of dimension and KPIs

No.	Dimension	KPI
1	Supply chain reliability	Perfect order fulfillment
2		Orders delivered in full
3		Order fill rate
4		Delivery performance to customer commit date
5		Delivered in perfect condition
6		Document accuracy
7	Supply chain responsiveness	Order fulfillment cycle time
8		Source cycle time
9		Make cycle time
10		Deliver cycle time
11	Supply chain flexibility	Upside supply chain flexibility
12		Upside supply chain adaptability
13		Downside supply chain adapability
14	Supply chain cost management (% of total revenue)	Supply chain management costs
15		Cost to source
16		Cost to make
17		Cost to deliver
18		Cost to return from customers
19	Supply chain asset management	Cash to cash cycle time
20		Return on supply chain fixed assets
21		Return on working capital
22		Sales outstanding
23		Inventory days of supply
24		Payable outstanding

units; second, the measurement system should evaluate performance holistically by measuring quantitative aspects as well as qualitative aspects [14]. The process performance measurement should answer these two questions: Is the current performance of the business process better than yesterday's? To what degree are the target values fulfilled? The main objective of a process performance measurement system is to provide comprehensive and timely information on the performance of business process, then it should not only serve as a warning system about performance problems, it should also communicate the reasons for the problems. It can be used to improve resource allocation, and process output regarding quantity and quality, to give early warning signals, to make a diagnosis of the weaknesses of a business process, to decide whether corrective action are needed and to assess the impact of actions taken.

1. The Process Maturity Supply Chain Performance Assessment

In 1995 the Software Engineering Institute suggested a different kind of solution to the performance management: the idea of concentrating on the process, rather than on the product. This leaded to the concept of evolutionary improvement of the process. The degree of effectiveness and efficiency of a process reflected the maturity of organizational practice, and was expressed through a capability maturity model (CMM). The model comprised a set of levels corresponding to the degree of process effectiveness and efficiency, and thereby indicated the capability of the organization to execute the process successfully.

Maturity means that the process can be controlled. CMM prescribes a set of key processes and practices that form the basic platform and provides a general approach for assessing the ability of an organization to manage it business processes. It consists of a series of key process areas and several maturity levels. A key process area refers to a cluster of related activities which aim at achieving a set of goals and contains prescriptions for a set of activities to be accomplished in the course of projects. Maturity levels are collections of key process areas. A maturity level defines the major characteristics of key business processes of an organization.

Meng et al. [18] proposed supply chain relationship maturity model based on capability maturity approach. The key components includes: (1) Assessment criteria. Assessment criteria are divided into eight main criteria, including procurement, objectives, trust, collaboration, communication, problem solving, risk allocation, and continuous improvement. (2) Maturity levels. Four maturity levels are developed. The first two levels represent traditional relationships and last two levels represent collaborative relationships. In general, the level 1 to level 4 represent respectively price competition, quality competition, project partnering, and strategic partnering/alliance.

Supply chain relationships are usually complex, multifaceted, and difficult to measure in a quantitative manner. However, to achieve relationship improvement and demonstrate such improvement, a measurement tool is needed. Assessment using this model not only helps to position an existing relationship on the maturity scale but also helps to identify areas where improvement is needed to achieve a higher maturity. This kind of assessment focuses on not only outcomes but also on the activities process.

2. The SCOR Model

The supply chain operations reference (SCOR) model that was introduced by the Supply Chain Council (SCC), who is an independent, not-for profit, global corporation interested in applying and advancing the stat-of-the-art in supply chain management systems and practices. SCC benchmarks operational measurement to create a prioritized improvement portfolio tied directly to a company's balance sheet for improving quality performance and profitability. SCOR is created as a process tool that describes, measures and evaluates any supply chain configuration and the effects of all business processes and performance on SCM of meet all customer demands, and is utilized as the standard diagnostic tool for the configuration of supply chain management. It provides a methodology for managing supply chain activities and process, which can be used as a set of practical guidelines for analyzing supply chain management practices. The SCOR-model integrates the concept of business process reengineering, benchmarking, and process measurement into a cross-functional framework. It spans all customer interactions, all market interaction.

SCOR comprises five components: plan, source, make, deliver and return. Each of these components is considered both an important intra-organizational function and a critical inter-organization process. It contains four levels of process details. The specific five metrics in two categories: customer-facing metrics, including reliability, responsiveness, and flexibility, and the internal-facing metrics, including cost and assets. The SCOR model includes the following elements as a communication platform for the practitioners of supply chain planning activities. (1) Standard descriptions of each business process along the supply chain are categorized as plan, source, make, deliver and return, and the supportive activities are defined as 'Enabler'. (2) Key performance indicators (KPI) are classified by the attributes accompanying each of the business process. (3) Best practices appear in the SCOR mode as recommendations if the diagnosis of certain processes by KPI shows a need for improvement. (4) Associated software functionalities are identified that can enable the best practices for business process reengineering.

The SCOR model begins with an 'As-Is' (current status) analysis to capture the existing level 1 and level 2 processes while revealing geographical context, transportation costs, and trading relationships between the entities of the current supply chain. At level 3, all SCOR processes are interconnected and running as an operation cycle of planning, execution, and enabling at a certain frequency. At level 4, the supply chain components are acting as the enabler with the work statements. Eventually, a user can analyze supply chain process using the model and implement an optimum SCM plan using different perspectives in the SCOR model, and conduct a quantitative analysis of process performance. The completed four levels become the guidelines for implementing supply chain management.

Lockamy etc. explored the SCM assessment based on four main decision area of SCOR model, such as plan, source, make and deliver, and result in the importance of collaboration, process measures, process collaboration, process credibility, process integration and information technology [16], and furthermore, defining five general levels of process maturity and analyzing the relationship of process maturity with SC performance.

Ge Wang et al. worked on product driven supply chain selection using SCOR, AHP and PGP combination has made supply chain management as a multi criteria decision making problem, where in the best possible way is selected to enhance the performance of the supply chain. In AHP decomposition tree, overall supplier efficiency was defined as the final goal followed by delivery reliability, flexibility, responsiveness, costs and assets as criteria level. These three valuable concepts of SCOR, AHP and PGP were restricted to supplier selection alone, which is just a part of the supply chain management process.

3. Module Performance Measurement Framework

Thakkar based the key papers in the domain of performance measurement, and provided 11 modules of preliminary conceptualization about SCM performance measurement [20]. The aim is to address these questions:

(1) How intra and inter-firm supply chain conflicts should be measured and analyzed?
(2) How should these aspects be incorporated in the measurement framework?
(3) How can a holistic framework be used to evaluate, improve and control the overall efficiency and effectiveness of a supply chain?

Module 1: Identify the processes, technologies and tasks being performed at intra and inter functional, organizational level;
Module 2: Recognize various supply chain entities and identify Vision, Mission, Objectives and Strategies;
Module 3: Identify commonality in strategic intent- shared vision, mission, objectives, strategies;
Module 4: Assess the requirements of external customers and internal customers;
Module 5: Carryout gap analysis and force-field analysis to gain detailed understanding on conflicting issues;
Module 6: Identify bottleneck areas/stumbling blocks in meeting supply chain objectives;
Module 7: Set a common strategic intent and seek the consensus of channel members;
Module 8: Identify shared performance measures for supply chain and seek the consensus of channel members;
Module 9: Evaluate the nature/orientation of metrics;
Module 10: Evaluate and improve current processes;
Module 11: Control & monitor process.

These modules can be used to help organizations to design and deploy performance measurement system toward aligning an organization's operation with its strategic direction and enhancing the overall efficiency of supply chain.

The concerns of futuristic performance measurement system about SC mainly includes [20]:

1. PMS associates with knowledge management, virtual organizations, organizational interactions and organizational agility.
2. PMS is understood within the integrated SC.
3. The future SC performance system should link with the strategy of an organization, be part of an integrated control system, and enable proactive management.
4. Searching for a suitable approach to aggregate the existing or new performance measures into the holistic, integrated performance measurement system to assess the SC.

An integrated approach for measuring supply chain performance is suggested, combining economic value added (EVA), the balanced scorecard (BSC), and activity based costing (ABC), clearly emphasizing the need of overhead handing and a balanced approach [23].

Researchers point to the problems of current performance measurement system, and provide clear evidence that the new/modern supply chain performance measurement system, and suggest different methods of supply chain performance measurement under the new supply chain era.

64.5 Conclusions

Organization successes confirm the power and importance of supply chain performance management as a cornerstone concept and practice within SCM. Improving the supply chain performance of the organization should appropriately select the metrics and analyze tools.

The performance measurement in SC should reflect a system and involve all members across interfaces. The supply chain measurement system is designed to measure not only the results but also other additional sides, specific to select practices such as cross-functional coordination, internal integration (functional and strategic business unit level), total quality management etc., to help the organizations to understand various management practices deployed in a given environment as a holistic system.

Modern management emphasizes process management and improvement continually, and needs a system approach to communicate the reasons for problems not just assess the financial data. Process-based performance assessment approaches provide methodologies for managing supply chain activities and process quantificationally and qualitatively, practice as guidelines, and span all sides.

The futuristic supply chain performance measurement should be better understand the organizations, align with the organizational strategies. In short, it should be a holistic and integrated performance measurement system to assess the SC.

Acknowledgments This thesis is funded by "2012 humanities and social sciences research base by SiChuan Provincial Department of Education, the research center of system science and enterprise development". Topics is XQ12C05.

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Chapter 65
δ-Shock Supply Chain Reengineering Decision Model Under Weibull Distribution

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Abstract After depicting the running status of supply chain system with δ-shock model under Weibull distribution, this research gives a quantitative decision-making reference of supply chain reengineering. Through the analysis of the examples, it finds that some system parameters, such as aging coefficient, running benefit, maintenance and replacement costs, will affect the long-run average cost per unit time and reengineering policy of supply chain system. Then the authors put forward some policy suggestions for supply chain management.

Keywords Supply chain reengineering · Core enterprise · δ-shock renewal process · Replacement policy

65.1 Introduction

Supply chain management is the dominant mode of business operation in world. In new century, the competition among enterprises is not competition between individuals but between their supply chains [1, 4]. Supply chain management emphasizes the integration of all firms and win-win of members. It's natural to observe and to analyze supply chain from view of system [10].

From a system perspective, it pays special attention to stability, reliability and risk manage-ment of supply chain, as well as the corresponding supply chain reengineering. Zhao and Yang [18] distinguish these concepts: stability, reliability and risk of supply chain system. The researches on stability of supply chain system concentrated on factors which affect the stability of the system, stability criterion of system, the elements of the system stability, the advice to improve stability and so on [2, 3]. The study subjects on reliability of supply chain system included reliability design, reliability assessment and analysis, simulation research etc [7–9, 17].

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_65,

Because risk brings uncertain return for supply chain, much attention has recently been paid to the study and practice of supply chain risk management. Main research scope of supply chain risk management includes risk source recognition, attribute analysis, risk classification, management strategy of various risk sources, risk management framework etc.

In latest research, using fluid synchronous research method in nonlinear dynamics, Yao et al. [16] discussed the mechanism of emergency event in supply chain and gave a solving method of its duration. As far as supply chain reengineering, the backgrounds of the problem include industry transfer [19, 21], horizontal merger [5], international division of labor, financial crisis, e-commerce [15], instant customization; related industries of the problem have book publishing, the press, pharmaceutical industry, retail, textile. Focusing on these fields, such as cost optimization, interest coordination of node enterprises, process control [14], value creation, competitive advantage etc, the corresponding literatures discuss the necessity and urgency of supply chain reconstruction [6, 13, 19, 20], analyze the characteristics of reconstruction and problem in reconstruction process, build a model and model of supply chain reconstruction, put forward some specific strategy and measures about reconstruction, and preliminarily evaluate the effect of reconstruction by quantification.

Because of several uncertainties within a node enterprise and between node enterprises at any time and complexity and variability of external environment, it is normal for operation of supply chain system to face uncertain shock or emergency [11, 12]. The aforementioned study on each side of supply chain system, both qualitative discuss or quantitative analysis, failed to answer the following questions of the supply chain system: How to evaluate the operation cost of supply chain system facing uncertain shock or unexpected events? Since the stability is very important, reengineering system is certainly uneconomic and is not conducive to the continued gains through supply chain if the core enterprise replaces the node enterprises for some small problems of node enterprise or supply chain system. So while core enterprise has faced the failure of supply chain, when to repair system itself by internal mechanism? When to replace the node enterprises, reselect partners and reconstruct the supply chain for the core enterprise?

This paper regards supply chain as a repairable system. Through depicting the running status of supply chain system with δ-shock model, the authors establish a repairable system model of supply chain, answer such questions, calculate the long-run average cost per unit time of supply chain system, and put forward some specific strategies of repair and reconstruction about supply chain system according to the results of numerical examples.

65.2 Model Construction

In a supply chain, problems of node enterprise itself, poor interflow between node enterprises, or mutation of external environment, all will result in a block of information flow, logistics and capital flow, a short chain interruption (such as operation cycle is disrupted, logistic and capital flow is broken, information sharing is interrupted, production and marketing is Seriously out of line) or complete disintegration, that is, system failed. All this will increase working costs of the supply chain and reduce reward of the whole supply chain and each enterprise. Factor that causes the system does not run smoothly or interrupt is collectively known as a shock, failure event, emergency or crisis event of supply chain. Taking the supply chain as a machine, occurrence of crisis event likes a part failure of a machine, the ordinary method is to repair the machine or directly replace parts or machine. In general, supply chain system can timely allocate logistics and capital flow through the internal forces, renovate the information system, reduce the damage and loss of emergency, and remove the congestion of information flow, logistics and capital flow. Seriously, the core enterprise will stop the partnership with node enterprise, reselect the cooperative partner, reengineer the supply chain system and recover well working of supply chain. It does not meet the requirements of supply chain system stability and face expensive reengineering cost that to directly replace node enterprise or to directly engineer the system when the supply chain system encounter crisis event. These costs include cost of terminate the agreement with the original members of the supply chain, cost of reselecting the partner of supply chain and cost of adapting the new partner (such as training costs for the new partner).

The new supply chain system will gradually run well through mutual adaptation of node enterprises. During normal operation, node enterprise will appear Inertia and lag in technology as the time goes. Now, the system would not meet the new market demand and the new requirements of development, with the running time increased, the normal operation time of the system is shorter and shorter, and time of repair after failure is longer and longer.

We can regard the crisis event that the supply chain faces as a shock. The system will generate random damage when supply chain is shocked by a crisis event. Based on the above analysis, just like many systems in real life, we can regard supply chain system as a degenerate system. Thus, we can use the geometric process to describe the working of supply chain system, use a random decrement geometric process to describe normal working hours of supply chain system, use a random increasing geometric process to describe the repair time after a system failure, and build a shock model to simulate the working of supply chain system.

The shock model is widely used and has been studied by many scholars. This paper will use δ-shock to simulate the crisis events that the supply chain faces. δ-shock model pays more attention to the frequency of shock rather than the cumulative damage caused by shock. In a δ-shock model, one shock is fatal if and only if the time interval is less than a certain threshold value between this shock and the last shock, and here the system will fail. The threshold value δ is usually a constant.

The following are some assumptions about δ-shock model of supply chain system:

1. When $t = 0$, the supply chain system is new, and the internal repair mechanism will work as soon as the system fail.

2. The supply chain system will take a shock, the shock is from a renewal process, and the time interval obeys Weibull distribution $W(\theta, \eta)$ with parameters θ and η. Its density function is

$$f(x) = \begin{cases} \theta\eta \times x^{\eta-1} \exp(-\theta x^{\eta}), & x > 0 \\ 0, & x \leq 0. \end{cases} \tag{65.1}$$

When the interval time obeys Gamma distribution, log normal distribution or other distribution, the model can be also analyzed.
3. The repairable deteriorating system after the repair will be more easily to failure. So the threshold value of fatal shock will increase with the number of times of maintenance or failure. As an approximation, we can assume that the threshold value increases with a geometric ratio as the system has more numbers of maintenance. Assumed that the supply chain system has repaired n times ($n = 0, 1, \cdots$) (if $n = 0$, it means that the supply chain system is new), so the corresponding threshold value with the fatal shock is $\alpha^n\delta$ and $\alpha \geq 1$. That is to say, the time of first shock arrival after n times repair is less than $\alpha^n\delta$, or the time interval between shocks is less than $\alpha^n\delta$, the supply chain system will fail. And the supply chain system will stop running while repairing it. There is no effective shock for it at the same time. Once the supply chain system completes maintenance, the shock begins again.
4. Because of aging, wear and tear of a deteriorating system, assume that time to repair after failure meets a geometric process with random increasing, the ratio is β and $0 < \beta < 1$. The average repair time of first failure is ν and $\nu \geq 0$. While $\nu = 0$, it means that the repair time of the dysfunctional supply chain can be neglected.
5. Because the shock process is from external and geometric process of repair is determined by the supply chain system itself, the renewal process of shock source and the geometric process of repair time are independent.
6. Reward per unit work time of supply chain system is r, the cost to reselect the node enterprises includes basic cost R and cost in proportion to selection-time Z with ratio c_p. The time Z to reselect the node enterprises is a random variable, its mathematical expectation is $E(Z) = \tau$.
7. When the number of system fault (failure) has reached N, the core enterprise will replace the original supply chain system with a new supply chain system.

We can say a cycle is completed if a replacement is done for a renewal process. Thus, a cycle is the time interval between new system and the first replacement, or between last replacement and this replacement, and successive cycles form a renewal process. A renewal reward process includes successive cycles and cost in each cycle. According to the renewal reward theorem, the long-run average cost per unit time is equal to (The average cost of a cycle/The average length of a cycle).

Now, let X_1 is the first running time of new supply chain system, X_n is the running time following $n-1$ times repair. Moreover, let Y_n is the repair time after n times failure. According to the theory of renewal process, the replacement strategy N is better than strategy T or even batch replacement strategies. This paper adopts the generalized replacement strategy N.

Let $W =$ the length of a cycle, so:

$$W = \sum_{n=1}^{N} X_n + \sum_{n=1}^{N-1} Y_n + Z.$$

For a supply chain system, when the time interval of shock arrival obeys Weibull distribution and the core enterprises use replacement strategy N as reengineering policy, the long-run average cost per unit time:

$$C(N) = \frac{c\sum_{n=1}^{N-1} \frac{\nu}{\beta^{n-1}} - r\theta^{-\frac{1}{\eta}}\Gamma\left(\frac{1}{\eta}+1\right)\sum_{n=1}^{N} \frac{1}{1-\exp -\theta(\alpha^{n-1}\delta)^{\eta}+R+c_p\tau}}{\theta^{-\frac{1}{\eta}}\Gamma\left(\frac{1}{\eta}+1\right)\sum_{n=1}^{N} \frac{1}{1-\exp -\theta(\alpha^{n-1}\delta)^{\eta}+\sum_{n=1}^{N-1}\frac{\nu}{\beta^{n-1}}+\tau}}. \quad (65.2)$$

After careful analysis, δ-shock decision model of supply chain system has a optimal replacement strategy (critical point of reengineering) N^*.

65.3 Numerical Examples

In above model, let $\alpha = 1.05$, $\beta = 0.95$, $\nu = 10$, $\tau = 35$, $c_p = 5$, $c = 3$, $r = 2$, $R = 100$, $\delta = 3$ and $\eta = 2.0$, $\vartheta = 1$.

Figure 65.1 has shown that $c(57) = 2.9746$ is the minimum value of long-run average cost per unit time. This means the core enterprise should consider the reconstruction of the original system after the supply chain failed 57 times. It also shows the running cost is high because the node enterprises need time to adapt each other for a new supply chain system. With supply chain life cycle coming into the growth and maturity, the supply chain steps into good operation period gradually and its running cost gets gradual optimization. At this time, the supply chain is most competitive and can make more value. After coming into recession, the supply chain system is aging, it is a inevitable choice for the core enterprise to decide system reengineering.

Based on the above calculation results, we can do further sensitivity analysis for the long-run average cost $C(N^*)$ per unit time and critical point N^* of reengineering of supply chain system on some important parameters in the above model.

1. Sensitivity Analysis of $C(N^*)$ and N^* on α

The followings are the value of the other parameters: $\beta = 0.95$, $\nu = 10$, $\tau = 35$, $c_p = 5$, $c = 3$, $r = 2$, $R = 100$, $\delta = 3$. Let α change in the vicinity of 1.05, Fig. 65.2 shows the corresponding changes of long-run average cost $C(N^*)$ per unit time and critical point of N^* reengineering with α changes. N^* has no change with α, but $C(N^*)$ will increase. When the other parameters are constant, the changes of α will lead to a change of threshold corresponding with a lethal shock. That is, with the addition of α, it will enhance the system vulnerability, a shock of a longer time interval may also make the supply chain system failure. This may not affect the decision-making about the critical point N^* of reengineering, but the optimal

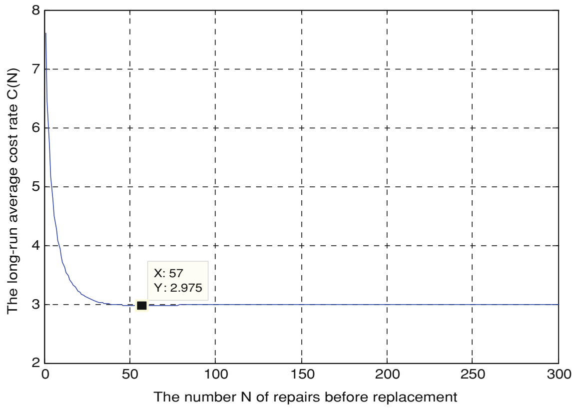


Fig. 65.1 Plot of $C(N)$ against N for Weibul dist

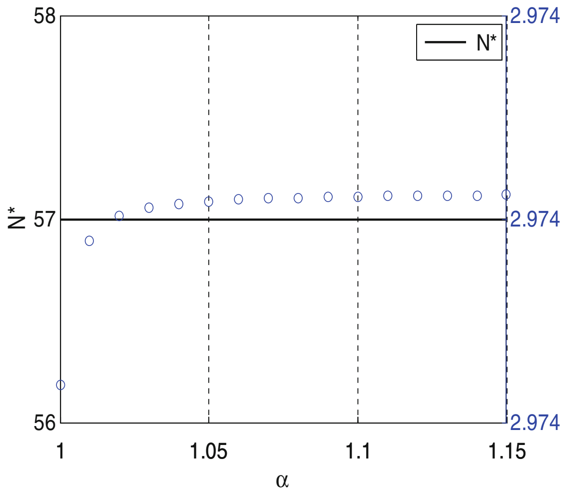


Fig. 65.2 Plot of N^* and $C(N^*)$ against α

cost $C(N^*)$ will increase inevitably in order to maintain operation of the vulnerable system.

2. Sensitivity Analysis of $C(N^*)$ and N^* on β

$\alpha = 1.05$, $\nu = 10$, $\tau = 35$, $c_p = 5$, $c = 3$, $r = 2$, $R = 100$, $\delta = 3$, Let β change in the vicinity of 0.95, Fig. 65.3 shows the corresponding changes of $C(N^*)$ and N^* with β changes. N^* will increase with the increase of β, while $C(N^*)$ will decrease with β. Because β is an aging and wear parameters of supply chain system, aging and wear of the system will be slower when β is larger. That means the system can withstand more impact, and the optimal replacement time N^* will grow. Accordingly, its long-run average cost per unit time will be less.

3. Sensitivity Analysis of $C(N^*)$ and N^* on δ

Fixed $\alpha = 1.05, \beta = 0.95, \nu = 10, \tau = 35, c_p = 5, c = 3, r = 2, R = 100$, Let δ change in the vicinity of 3, Fig. 65.4 shows the corresponding changes of $C(N^*)$ and

Fig. 65.3 Plot of N^* and $C(N^*)$ against ρ

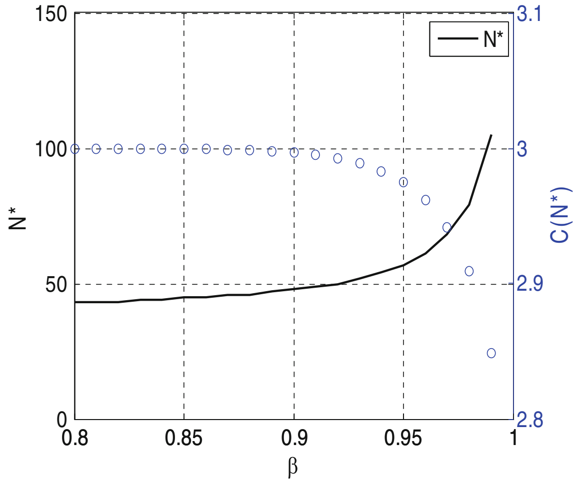
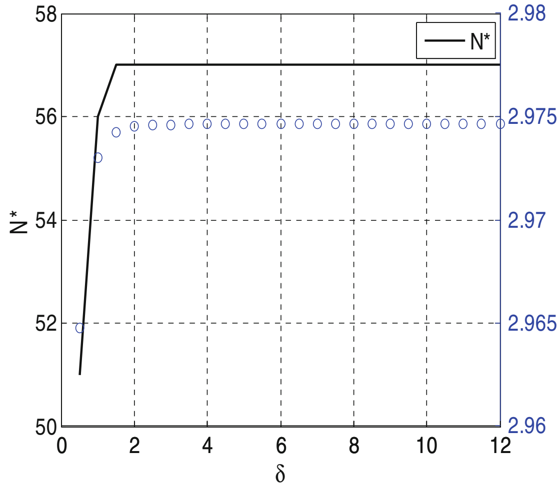


Fig. 65.4 Plot of N^* and $C(N^*)$ against δ



N^* with β changes. When δ increases, the numerical value of the optimal replacement strategy N^* will increase at first and then tend to stable, and the long-run average cost $C(N^*)$ per unit time increases. The basic principle of δ is similar with α, the change of δ will result in supply chain system failure even if it gets a shock after a long time since the last shock, that means the supply chain is more vulnerable.

4. Sensitivity Analysis of $C(N^*)$ and N^* on ν

Fixed $\alpha = 1.05$, $\beta = 0.95$, $\tau = 35$, $c_p = 5$, $c = 3$, $r = 2$, $R = 100$, $\delta = 3$, Let ν change in the vicinity of 10, Fig. 65.5 shows the corresponding changes of $C(N^*)$ and N^* with δ changes. When ν increases, N^* will decrease and $C(N^*)$ will increase. ν is the average repair time of first failure for the supply chain system, the

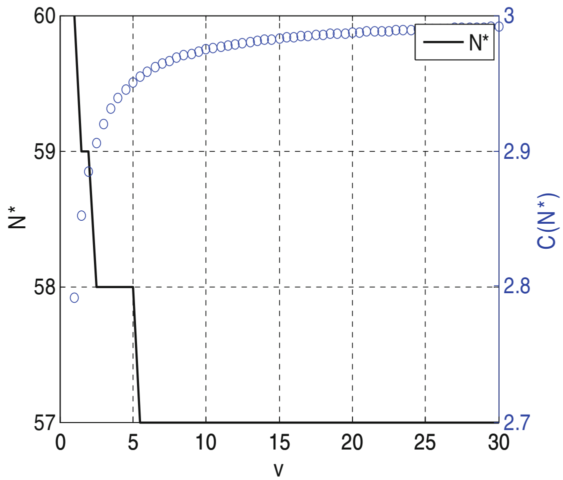


Fig. 65.5 Plot of N^* and $C(N^*)$ against ν

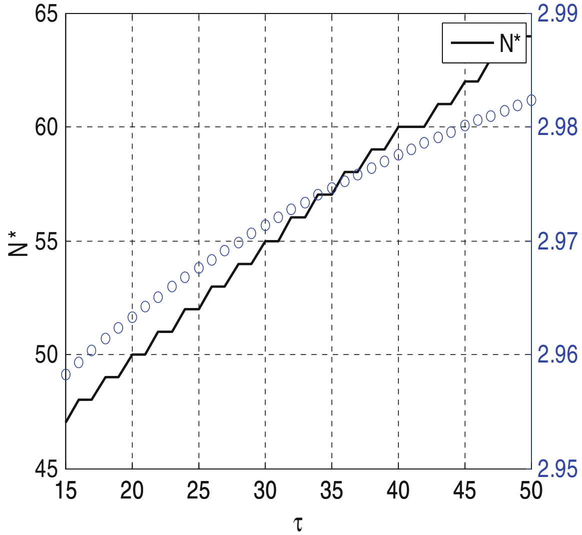


Fig. 65.6 Plot of N^* and $C(N^*)$ against τ

smaller the value of ν is, the stronger the repair ability of the supply chain system itself is, the better reliability and stability of the new supply chain system is. At this time, even if the failure happens, it costs only a very short time to repair, so it is needed much less for long-run average cost per unit time of supply chain system, and the system can withstand more times shock before reengineering.

5.Sensitivity Analysis of $C(N^*)$ and N^* on τ

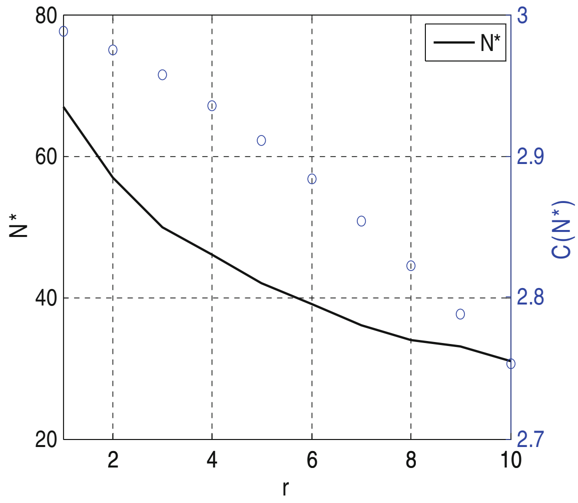


Fig. 65.7 Plot of N^* and $C(N^*)$ against r

Fixed $\alpha = 1.05$, $\beta = 0.95$, $\nu = 10$, $c_p = 5$, $c = 3$, $r = 2$, $R = 100$, $\delta = 3$, Let τ change in the vicinity of 35. Figure 65.6 shows $C(N^*)$ and N^* increase with τ. τ is the time that the core enterprise reselects node enterprises, or calls time cost of supply chain reconstruction. When τ increases, it shows the time cost of supply chain reconstruction is more, thus people tend not to easily replace the node enterprises of supply chain system, N^* becomes larger, and the optimal long-run cost increases naturally.

6. Sensitivity Analysis of $C(N^*)$ and N^* on r

Fixed $\alpha = 1.05$, $\beta = 0.95$, $\nu = 10$, $\tau = 35$, $c_p = 5$, $c = 3$, $R = 100$, $\delta = 3$, Let r change in the vicinity of 2. Figure 65.7 shows the corresponding changes of $C(N^*)$ and N^* with r changes. $C(N^*)$ and N^* decrease with r increasing. r is the reward per unit time of supply chain system. The increase of r shows that the system brings the more benefit to supply chain, long-run average cost $C(N^*)$ per unit time of supply chain is reduced accordingly. At this time, the critical point N^* of reengineering of supply chain system is also smaller, that means people tend to reconstruct the supply chain system as soon as possible when the system faces uncertainty shock, rather than bear the damage caused by risk of supply chain system. This is an interesting phenomenon.

65.4 Conclusions

After depicting the running status of supply chain system with δ-shock model under Weibull distribution, this paper evaluated the long-run average cost per unit time of supply chain system, gave some quantitative basis for decision-making of supply chain system reconstruction.

Through the above analysis, some conclusions can be drawn as follows, which is worth reference to the supply chain management.

1. The critical point N^* provides a basis for decision-making of supply chain system reengineering. They are acceptable that some problems exist in the operation process of supply chain system and cause no serious influence. However, if the problems of node enterprises appear again and again, affect operation efficiency of supply chain system, we should pay more attention to them. The replacement strategy N^* reminds managers of supply chain or the core enterprises to timely examine the operation, evaluate the internal efficiency, evaluate the partners of supply chain, optimize the process, keep the chain smooth, ensure the effectiveness and agility, etc. All these make the supply chain be more competitive and obtain more benefits.
2. To reengineer the supply chain on right time is a problem that the core enterprise of keeping pace with the times should think about. Factors which influence the decision of supply chain reengineering mainly include the system parameters, performance parameters and cost parameters. System parameters include system aging or worn parameter β and parameters associated with the shock threshold α δ etc. Performance parameters mainly refer to income r per unit time of the running supply chain system. The cost parameters include the average repair time ν of supply chain when the system was shocked and the average time τ of selecting new node enterprise when the core enterprise reconstructs the system. Therefore, a supply chain system does not put things right once and for all, all node enterprises must learn more and keep pace with the times in order to maintain the energy of the supply chain system. On the other hand, from the view of core enterprise, they should spend time on searching and reserving other node enterprises, keeping in touch with the cooperative enterprises. So these measures will reduce the cost of reengineering system in case of emergency.
3. Collecting and sharing information will contribute to supply chain management. Supply chain management includes business flow, logistics, information flow and capital flow, all these factors interact and inseparably linked with each other. Only through the transfer and exchange of information, we can let the node enterprises be integrated whole and show the overall competitiveness of the supply chain. Depicting the running status of supply chain system with δ-shock model, decision of system reengineering is related to time interval and numbers of shock. With the help of supply chain integration information system, all kinds of information are got a record and feedback in real-time that they have generated in the operation process of supply chain, including various uncertainty information that influence operation of supply chain. It is crucial for evaluating supply chain efficiency and considering reengineering decision to save the information. Strengthening the construction of supply chain information system is an important part of supply chain management!

Acknowledgments This work was supported by Key Project of Sichuan Provincial Education Department (13ZA0064).

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Chapter 66
Role of Talent Management, Diversity Trainings and HRD on Effective Implementation of HR Practices in Telecom Sector in Pakistan

Muhammad Imran Hanif, Yunfei Shao, Muhammad Ziaullah and Muhammad Shahzad Hanif

Abstract The purpose of this paper is to analyse the previous studies, take qualitative input and feedback of senior HR experts of telecom sector to scroll the importance of integration of diversity management and talent management practices. Another objective is to study practical implications and contribution of Human resource development in coordinating these strategies. The significance of the current study is to provoke the integration and importance of delivery of diversity trainings in liaison with Talent Management practices and strategies. This study aims to highlight the importance of Human resource development and its contribution in retention of employees. Secondly, to build strong relation and impact effective and efficient implementation of HRD with talent management strategies.

Keywords Diversity trainings · Talent management · Human resource development · Innovation · HR practices · Diversity management

66.1 Introduction

Diversity management and Talent Management have similarities and applications for attraction, recruitment, selection, retention of employees, employees growth and development, engaging them, promotion of workforce, motivating and excitement employees [2, 9]. The philosophies and strategies of talent management (TM) and managing diversity are very common these days and their effective and efficient implementation through HR, both are uncertain with no established or decided

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_66,

sense [17]. TM has developed its importance as new Human Resource [3]. The focus of both talent management and diversity management comprises implications for the HR core strategies related to newly established reward communication, employee retention, training and development, employee relations, and engagement. These both possess learning techniques and newly developed methodologies as integral components in professional practice and application.

Kamil and Salleh [11] highlighted that talent management has become a new innovation of human resource practices. The importance of talent management practices to enhance business performance is realized recently. The significance of the current study is to provoke the integration and importance of delivery of diversity trainings in liaison with Talent Management practices and strategies. These study focus on the importance of Human resource development and its contribution in retention of employees. Secondly, to build strong relation and impact effective and efficient implementation of HRD with talent management strategies. Furthermore, how to manage diverse workforce with equal employment opportunities? The issues of attraction of talent and retention of employees are getting roots in these days especially in telecom sector. Multinational companies are approaching to intake professionals, expatriates and diverse workforce to achieve economies of scales and to maximize the productivity and output for the organization. At expert level they are treated differently keeping in view their concepts and studies, but set of ideas are directing to interlink the strategies and to build a framework that will work together to retain and promote employee e keeping in view different interests of individuals and organization, study was conducted in different academics [12, 17].

The problem statement of this paper is Research is needed to speak to the relations between talent management and managing diversity as one instance to achieve better addition and less departure in academic work on human resource. At hand is a quantity of incomplete proof that experts view dissimilar areas of HR tradition in separation and do not built associations in preparation as well as they could. This confirmation is taken as adequate support for the need for more research into the proposal. The purpose of this paper is to analyse the previous studies, take qualitative input and feedback of senior HR experts of telecom sector to scroll the importance of integration of diversity management and talent management practices. Another objective is to study practical implications and contribution of Human resource development in coordinating these strategies.

66.2 Literature Review

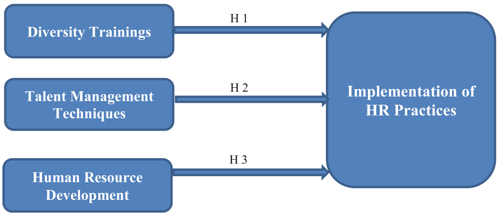
Hanif and Shao [8] highlighted that the impact of talent management strategies has remarkable effects on human resource perceived outcomes especially on output, efficiency and productivity of organization and employees. They further elaborated that profitability increases automatically whenever the employees are willing to serve with a clear vision, ideology and long term sustainability approach with their parent organization. Swapna and Raja [16] worked on role of talent management with reference of service sector. She said that talent management is integral for business transformation success. Dries et al. [4] identified three sets of assumptions of careers and concluded that traditional organzations careers provide better satisfaction for careers with respect to career displaying of employees. It yielded more satisfaction of individual careers rather than personal career orientation. Farashah et al. [5] studied the role of succession planning in building employees career attitude. Hanif [7], answered the questions that how we can produce diverse workforce in shape of fresh graduates available for recruitment. They also highlighted that how HR of leading public and private organizations can recruit diversified potential, competitive personality characters and traits within a culture.

There was a move from an Equal Opportunity towards diversity focus in late 1990s. The varying and geographic, social, demographic drivers were influencing the organizations and corporations of twenty-first century, have now turned the demands in the direction of enlarged exhibition of diverse community groups and persons in the workforce [15]. Ali et al. [1] elaborated the recruitment and selection techniques as the key source for attracting and retaining of employees. They expressed those recruitment strategies such that employee referral programs and retention, building, career development and acquisition and human resource development (HRD) should be ranked as the chief source for talent retention.

Morton [13] said that organizations are working on retaining their employees and following different strategies. i.e. HR generic strategies to retain their top talent. Talent management is an integral part of the talent retention, elaborated by Lewis and Heckman [12]. They further said that talent management is important for the organizations and it consists of HR practices like recruitment, selection, development and career management, employer branding, motivation and training and development. Zheng [18] described the importance of talent retention in his work for the organizational performance. In his work he highlighted the HRM practices as independent variables and their impact on the employee retention and organizational performance which were shown as dependent variables. In the area of future research he suggested the need of talent management along with HR practices to get better results. Pollit [14] described, succession planning as a tool to develop the leaders for future and to review the talent regularly for retention purposes.

With respect to Human Resource Development, it is least researched area and possesses little evidence till now to ask whether professional practice will adequate guide or hinders developing connections. Perchance, it is not strength rather than a weakness in current area of research and the information gathered needs further exploration. We have conducted interviews with HRD specialists in the telecom organization and discussed in detail about the matter of connectivity but not satisfied by the results. Our research will persist all the way through more interviews and group discussions and we will circulate questionnaires to further investigate the real matter and try our best to access to the documentary analysis and collect non-participant observation and feedback.

Fig. 66.1 Conceptual model



1. Conceptual model

Based on the in-depth literature review, researcher has proposed the following model. Independent variables in hypothesized model are Diversity Trainings, Talent Management techniques and Human Resource Development. Dependent variable is Implementation of HR practices in telecom organizations in Pakistan (Fig. 66.1).

2. Research hypothesis

Three hypotheses have generated on the basis of above hypothesized model. Therefore, the study hypothesizes:

Hypothesis 1 Diversity Trainings have positive impact on effective implementation of HR practices;

Hypothesis 2 Talent Management Techniques (i.e. Succession Planning and Employer Branding) have positive impact on effective implementation of HR practices;

Hypothesis 3 Human Resource Development Techniques (i.e. Succession Planning and Employer Branding) have positive impact on effective implementation of HR practices.

66.3 Methodology

A structured questionnaire was used as instrument to prove the hypothesis and for the results appropriate statistical tools will be used for the analysis. The both qualitative and quantitative techniques were adopted and for the purpose of primary data collection, organizations from telecom sector were selected as target segment. Interviews and discussions were held those help the authors to determine the results.

1. Sample design and data collection

The population of the study was telecom organizations in Pakistan. The sample data was gathered from top HR professionals and training and development departments of leading telecom companies operating in Pakistan. The companies included Pakistan Telecommunication Company Limited and Telenor Pakistan and Warid telecom. I selected the organizations those already have an HRIS department and use computer based information systems for conducting their business operations.

The study required experts. opinion due to the nature of the constructs used. So, the author used non-probability purposive sampling technique. The author find it an appropriate sampling technique when target population was small in number and respondents experts of the subject matter. Therefore, the issue of generalizability in the purposive sampling can be overcome by including data of all available experts.

For data collection, we divided the structured questionnaire into four parts. First part of the instrument contains the items of Diversity trainings and questions for Training and Development department and was distributed to Senior HR managers, HR manager, Trainers, consultants and HR experts. Whereas, the second part of the instruments have the items of Talent management which were distributed to Senior HR Professionals of telecom sector. Third part will relate questions related to HRD and final one was asked questions related to implication of HR practices. Before sending the questionnaire to each telecom operator, it was pre-tested through academic reviews and opinions, discussions with business and HR experts. For data gathering, companies. executives were contacted through telephonic calls, emails, and through letters for their participation in the survey. After the affirmative responses, 200–250 questionnaires were send to get the response. A covering letter briefing the study and its objective was enclosed with each questionnaire.

2. Instrument

All the items were measured on a 5-point likert scale. The 5-point likert scale was used for four exogenous variables: “Diversity Trainings” and “Talent Management”, “Human Resource Development” and a dependent variable “effective HR” checks the level of agreement, ranging from 1 = “strongly disagree” to 5 = “strongly agree”. The instrument is adopted from Victoria and Steward and questionnaire is designed according to under process research paper.

66.4 Statistical Analysis

1. Correlation analysis correlations

Table 66.1 depicts correlation analysis between three independent variables including HRMP, TM, CV, mediating variable ER and a dependent variable namely FP. This Table 66.1 shows that value of HRMP in relation to HRMP is 1. The value of TM in relation to HRMP is 0.764 and in relation to TM is 1. The value of CV in relation to HRMP is 0.798, in relation to TM is 0.931 and in relation to CV is 1. The value of ER in relation to HRMP is 0.968, in relation to TM 0.704, in relation to CV is 0.743 and in relation to ER is 1. The value of FP in relation to HRMP is 0.504, in relation to TM is 0.504, in relation to CV is 0.501, in relation to ER is 0.270 and in relation to FP is 1. All values show that there is a significant positive relationship between independent variables HRMP, TM, CV, mediating variable ER and a dependent variable FP.

Table 66.1 Correlation analysis

		HRMP	TM	CV	ER	FP
HRMP	Pearson correlation	1				
TM	Pearson correlation	0.764[a]	1			
CV	Pearson correlation	0.798[a]	0.931[a]	1		
ER	Pearson correlation	0.968[a]	0.704[a]	0.743[a]	1	
FP	Pearson correlation	0.504[a]	0.504[a]	0.501[a]	0.270[a]	1

[a] Correlation is significant at the 0.01 level (2-tailed)

Table 66.2 Regression analysis

Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.969[a]	0.939	0.939	0.11887

[a] *Predictors* (constant), CV, HRMP, TM

Table 66.3 ANOVA[b]

	Model	Sum of squares	Df	Mean square	F	Sig.
1	Regression	73.581	3	24.527	1735.829	0.000[a]
	Residual	4.748	336	0.014		
	Total	78.329	339			

[a] *Predictors* (constant), CV, HRMP, TM
[b] *Dependent variable* ER

Table 66.4 Coefficients

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	−0.165	0.059		−2.793	0.006
	HRMP	0.929	0.020	1.035	46.265	0.000
	TM	−0.073	0.039	−0.070	−1.888	0.060
	CV	−0.018	0.040	−0.018	−0.443	0.658

2. Regression analysis of HRMP, TM and CV on ER model summary

Table 66.2 depicts model summary of regression analysis between three independent variables including HRMP, TM, CV, mediating variable ER and a dependent variable namely FP. Table 66.2 shows that value of R is 0.969, the value of R square is 0.939, the value of adjusted R square is 0.939 and the value of standard error of the estimate is 0.11887. Positivity and significance of all values shows, the model summary is also significant and therefore give a logical support to the study model.

3. ANOVA

Table 66.3 depicts ANOVA (Analysis of Variance) of regression analysis between three independent variables including HRMP, TM, CV, mediating variable ER and a dependent variable namely FP. On one hand Table 66.3 shows that in regression, the value of sum of squares is 73.5818, the value of df is 3, the value of mean square is

Table 66.5 Regression analysis

Model	R	R square	Adjusted R square	Std. error of the estimate
1	1.000[a]	1.000	1.000	0.00000

[a] *Predictors* (constant), ER, TM, CV, HRMP

Table 66.6 Coefficients

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	−5.751E−14	0.000			
	HRMP	5.000	0.000	3.820	–	–
	TM	−5.059E−14	0.000	0.000	–	–
	CV	1.514E−14	0.000	0.000	–	–
	ER	−5.000	0.000	−3.427	–	–

24.527, the value of F is 1735.829, and the significance value is 0.000. On the other hand in residual, the value of sum of squares is 4.748, the value of df is 336, the value of mean square is 0.014. Hence making a total of 78.329 as a sum of squares and 339 as a df. Positivity and significance of all values shows that model summary is also significant and therefore gives a logical support to the study model.

4. Coefficients

Table 66.4 depicts coefficient of regression analysis between three independent variables including HRMP, TM, CV, mediating variable ER and a dependent variable namely FP. Table 66.4 shows that in constant, the value of B is −0.165, the value of standard error is 0.059, the value of t is −2.793, and the significance value is 0.006. In HRMP, the value of B is 0.929, the value of standard error is 0.020, the value of Beta is 1.035, the value of t is 46.265, and the significance value is 0.000. In TM, the value of B is −0.073, the value of standard error is 0.039, the value of Beta is −0.070, the value of *t* is −1.888, and the significance value is 0.060. In CV, the value of B is −0.018, the value of standard error is 0.040, the value of Beta is −0.018, the value of t is −0.443, and the significance value is 0.658. The table contains both positive as well negative values. It further shows that independent variables are HRMP, TM, CV.

5. Regression analysis of HRMP, TM, CV and ER on FP model summary

Table 66.5 depicts model summary of regression analysis between three independent variables including HRMP, TM, CV, mediating variable ER and a dependent variable namely FP. Table 66.5 shows that value of R is 1.000, the value of R square is 1.000, the value of adjusted R square is 1.000 and the value of standard error of the estimate is 0.00000. Positivity and significance of all values shows that model summary is also significant and therefore gives a logical support to the study model.

6. Coefficients

The coefficients are shown in Table 66.6.

66.5 Discussion

Talent management and Diversity management have become integral strategies and approaches for International Human Resource practices and is a commitment for widely shared belief that human resources are organization's top priority objective and source of competitive advantage. Hughes and Rog [10] highlighted the benefits of implementing effectively and efficiently a talent management practice include for betterment of employee recruitment process, rate of retention and focuses how to engage employees for long period of time. These results were conditioned to improved financial and operational performance of the organization. The talent management practices in liaison with human resource generic strategies contribute to improve the relationship between recruitment, employee engagement and talent retention.

Lewis and Heckman[12] revealed that talent management and HRD is comprised of collection of HR practices i.e. recruitment, staffing, selection, career development, employer branding and succession planning. Furthermore, they said that concept of talent management focuses on modeling and predicting the flow of human resource in entire organization is based on workforce skills, demand and supply, and the growth of human resource. The perceived HR outcomes can be achieved by Employer branding, performance appraisal, reward policy, sourcing and developing career planning. Today it is very important for Human Resource managers to track, built, facilitate and launch talent management systems and efforts that will develop organizational commitment towards talent management.

Morton [13] said that HRD and Diversity trainings are vital and crucial to engage employees in organization. Effective talent management guarantees that organizations can achieve the objective to retain talent. The survey and questionnaire results show that HR practitioners shared their views that the qualities to retain and attract employees and to recruit new talent are major issues in today major problems faced by HR. Employees share their problems and why they are not satisfied with their jobs and why they search their new jobs after short time period? Low salaries, bad environmental conditions, stress of work, health and safety conditions, harassment, poor work-life balance, lack of facilities, low fringe benefits, working hours, workforce attitude and management practice and behaviour were major issues highlighted by employers from different management cadres serving in different public and private sector organizations.

Fuelling these current issues and challenges Hughes and Rog [10] described the management's traditional techniques on minimizing labour cost. The focused interview and survey revealed that growing organizations are much committed to provide employees with a positive attitude of employer branding and the Human resource departments and divisions are more focused on establishing the talent management practices in practice rather than in words. The importance of talent management and need to retain the talent has been realized by organizations and they are positively making such generic strategies of human resources i.e. recruitment and selection, training and development, performance appraisal, motivation with a flayer and introduction of succession planning, employer branding and learning the mimetic approach of successful organizations history of talent management implementation strategies. The drivers to engage HRD, TM play vital role in implementation of efficient and effective HRD practices. These help in retain quality employees are an open secret and they include best salary packages, capacity building with required and desired skills, training and development, manager have realized how to motivate their sub-ordinates, satisfaction of employees with organization decisions, retirement benefits, how to appraise the force, trust and integrity, personal relationship with one's manager, employee development, fairly compensation and benefits and nature of the job. According to Gibbons [6], employee engagement is highly intellectual and emotional connection that an employer has for his or her job, organization, manager or co-worker that in turn influences him or her to apply additional discrepancy effort to his/her work.

66.6 Conclusion, Limitations and Future Research

It can be concluded on the recommendations and findings of the above research that the effectiveness of HR strategies is dependent on the consistency, clarity, credibility, and associated investments in the diversity trainings, succession planning and employer brand. The key retention factors best salary packages, capacity building with required and desired skills, training and development, manager have realized how to motivate their sub-ordinates, satisfaction of employees with organization decisions, retirement benefits, how to appraise the force, trust and integrity, personal relationship with one.s manager, employee development, fairly compensation and benefits and nature of the job. Strong HR practices and strategies implementation is related to professional development and individual development and employer brand those becomes the cause of satisfaction among employees and it enhances their performance in the organization. Engagement of employees can be improved in organizations by career development, leadership effectiveness, relational creativity, training, development, and motivation. Talent management practices play integral role in keeping the talent but the liaison and embedding of talent management strategies along with the human resource generic strategies i.e. recruitment and selection, training, career development, performance appraisal, motivation. Succession planning and employer branding are very importance for enhancing and implementation of concepts and practices of talent management. The impact of diversity trainings and HRD has remarkable effects on human resource perceived outcomes especially on output, efficiency and productivity of organization and employees. The profitability increases automatically whenever the employees are willing to serve with a clear vision, ideology and long term sustainability approach with their parent organization.

The study is restricted to telecom sector and selective organizations are selective as sample size. The research work shows that only Pakistan Telecommunication Company limited and Telenor employees were selected for sample size. The impact of restructuring, downsizing and rightsizing in PTCL and other telecom organizations is not elaborated. In future, it is recommended that the scope of research work can be further justified in service industry. All major players of telecom industry should be included to take input for impact of HRD, talent management and diversity trainings. The interaction and integration of these strategies may be explored in other sectors of the economy. A comparison work is suggested between developing countries in south Asia.

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Chapter 67
Cooperative Quality Investment in Outsourcing and Its Impact on Supply-Chain Performance

Jingxian Chen

Abstract This paper highlights the importance of cooperative quality investment (CQI) strategy and proposes a simple proportional investment sharing schedule in outsourcing of a supply chain, which consists of a single contract manufacturer (CM) and one original equipment manufacturers (OEM) whose demands are both sensitive to price and product quality. A three-stage dynamic game-theoretic framework is applied to describe decisions of every entity. In particular, we analyze two possible decision structures of quality choice: the CM optimally sets product quality and the OEM chooses product quality. By the backward induction approach, we obtain the analytical equilibrium solutions for each decision scenario. We find that if the CM is willing to share sufficient large investment fraction, the CQI strategy will be beneficial to quality enhancement no matter who sets product quality level. On the respect of equilibrium payoffs (profits), this study shows that each of the players always prefers to have complete control on quality choice with implementation of the CQI strategy. In addition, the supply-chain performance can be improved by practicing the CQI strategy. Furthermore, we explicitly put forwards the conditions for realizing this improvement.

Keywords Supply chain · Outsourcing · Quality improvement · Performance

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_67,

67.1 Introduction

In the early 1990s, business gurus such as Peter Drucker and Tom Peters challenged companies to "do what you do best and outsource the rest" [31]. Thereafter, many business leaders took this advice and a rapid increase in outsourcing can be found in late 1990s and the first decade of twenty-first century. Nowadays, outsourcing is a pervasive feature of supply chain and has contributed significantly to the growth of global economy. Firms in different industries increasingly consider outsourcing as a strategic option to reduce cost, improve quality, increase productivity, and enhance core competencies [33]. A new report stated that Pacific Rim Countries accounted for 46.6 % of total United States manufactured imports and China accounted for 54.7 % (about 25.5 % of total manufactured imports) of United States manufactured imports from Pacific Rim Countries in 2012 [21].

Many business practices have verified the advantages of supply chain outsourcing strategy, such as Nike has used outsourced providers to help them dominate the footwear, capturing and building a 47 % market share [31]. However, some argue that more reliance on outside suppliers is likely to lead to a loss of overall market performance due to issues such as the loss long-run of research and development (R&D) competitiveness, incompatible strategy goal, long lead-time, lower control on quality, higher transaction costs, poor delivery reliability, and the loss of in-production capability [12, 31].

As a well-known downside of outsourcing, low control on supplier's (i.e., contract manufacturer, CM) quality may cause supplier having no incentive on quality investment which ultimately incurs poor product quality. Therefore, the customer manufacturer (i.e., original equipment manufacturer, OEM) should define some incentive mechanisms for improving product quality to enhance competitiveness in the terminal consumption market. How to encourage the CM to improve quality in outsourcing? This is an interesting but challenging topic focused by the managers. In practice, strengthening quality inspection is always used to implement quality control on supplier's quality. Despite a more rigorous quality standard will be beneficial to the OEM for enhancing quality competence in the end market, it may deeply hurt the CM and even disrupt supply chain due to the pressure of standard implementation. For example, one factory of the giant CM Hon Hai Limited (also known as Foxconn Technology Group) in Chinese mainland breaks out a large-scale strike incurred by the instruction to strengthen quality inspections for the iPhone 5 was given by the OEM customer Apple Inc. [9]. Some procurement and supply chain managers suggest that the OEM should pay for the CM's quality improvement [27]. With consideration of this advice, this paper will propose a simple vertical quality cooperation schedule for encouraging quality improvement and explore its effects on quality choice and supply chain performance.

Cooperative quality investment (CQI, thereafter) is not a novel definition in literatures, Banker et al. [2] has studied the impacts of quality cooperation on product quality. Moreover, as they cited in the paper, the Big Three automakers practice this cooperation to battery technology for electric vehicles. The cooperation discussed in their study is between two enterprises at the same echelon of supply chain, i.e., a horizontal cooperation. However, this paper will focus on vertical quality cooperation strategy and aim to provide insights by studying the interactions among players in supply chain outsourcing. To our best knowledge, this kind of quality cooperation strategy obtained little attention in the extant literatures. However, it is commonly seen in practice such as Toyota Motor Co., Ltd. begining to cooperate on its supplier for improving product quality since 1970 [28].

In this study we employ the game-theoretic approach to model the CQI strategy in supply chain outsourcing and use the backward induction technique to derive equilibrium solutions of quality, prices and profits for each member. In our model framework, we propose a simple proportional sharing schedule for quality investment, i.e., the OEM will share partial quality investment expenses for compensating CM's quality expenditure. Thus, a question may naturally arise: who controls quality choice? Because each supply chain member has a different profit function with regard to quality, which may yield different optimal quality level and in turn affect quality investment expenses and profits. Thus, the power configuration of quality decision plays an important role in our model. Enlightened by the famous "Manufacturer Stackelberg" and "Retailer Stackelberg" models proposed by Choi [6], we consider two kind of channel power structures: The CM has complete control on quality decision versus the OEM has complete control on quality decision. We find that if the CM is willing to share sufficient large investment fraction, the CQI strategy will be beneficial to quality enhancement no matter who sets product quality level. On the respect of equilibrium payoffs (profits), this study shows that each of the players always prefers to have complete control on quality choice with implementation of the CQI strategy. In addition, the whole supply chain profit can be improved by practicing the CQI strategy. Furthermore, we explicitly put forwards the conditions for realizing this improvement. In other words, we show that implementing CQI strategy could be valuable for supply chain.

The rest of the paper is organized as follows. Section 67.2 briefly reviews the related literatures, and Sect. 67.3 details our key assumptions and notations. In Sect. 67.4, we investigate two decision models of quality choice: The CM optimally sets product quality and the OEM has complete power on quality decision, respectively. Section 67.5 discusses the effects of the CQI strategy on quality improvement and equilibrium profits, as well as supply chain performance. Concluding remarks and future directions are presented in Sect. 67.6.

67.2 Literature Review

Non-price competition is observed in many industries and well-studied in economics and marketing literatures. As an important non-price competitive feature in the majority of industries, product (service) quality has received intensive attention. Some Pioneering studies have investigated the market equilibrium and social optimum value for product quality of a monopolist [22, 25, 26]. These basic models were extended to discuss oligopolists competing on quality with a constant or zero quality cost of single product by Dixit [8] and Gal-Or [10]. Moorthy [20] later employed a quadratic function to describe quality cost and studied the noncooperative game model between two identical oligopolists whose consumers preferred a higher quality product to lower quality product. With a similar quadratic quality cost function for single product, Banker et al. [2] studied the noncooperative game model between two competing manufacturers who faced a linear demand pattern and how quality was influenced by competitive intensity. Other related literatures on this topic include Rhee [24], Villas-Boas [30], Desai [7], and so on. More recently, Yayla-Küllü et al. [37] studied multiproduct quality competition with consideration of limited capacity. As a strategic issue, quality in these works is referred to both design and conformance quality characteristics that are of interest to the customer when evaluating the product offered by the firm (see Garvin [11] for an excellent summary of quality definition). However, these works did not investigate the strategic interaction among players in the environment of supply chain channel.

Researchers in marketing and operations have pushed quality choice into the framework of supply chain. We refer to the seminal work by Reyniers and Tapiero [23] that highlighted the importance of strategic quality choice in a supplier-producer supply chain. Chambers et al. [4] analyzed the impact of variable production costs on competitive behavior in a duopoly where manufacturers compete on quality and price in a two-stage game. Xu [36] investigated a joint pricing and product quality decision in a manufacturer-retailer channel, in which the manufacturer sells a product through the retailer. Xie et al. [34] studied a quality investment and price decision model in a supplier–manufacturer supply chain. They considered the risk-averse behavior in the different supply chain channel strategies: Vertical Integration, Manufacturer's Stackelberg and Supplier's Stackelberg. They also proposed a quality decision model with an exogenous price for the competing supply chain [35]. Moreover, Xiao et al. [33] examined strategic outsourcing decisions for two competing supplier–manufacturer supply chains in which the manufacturers' key components have quality improvement opportunities. In addition, a few papers started to study manufacturer's quality decision and retailer's effort decision with considering a quality and effort-induced demand pattern in a manufacturer–retailer supply chain in which the manufacturer distributed a chosen quality product through the retailer by using a simple wholesale pricing contract. See Gurnani and Erkoc [15] and Ma et al. [19] for additional information.

Another group of researchers recognized asymmetric quality-related information such as quality level and quality cost could be vital to quality choice for supply chain's players. Thus, many related contractual agreements are developed for mitigating the impacts of asymmetric quality information. Examples include Baiman et al. [1], Ma et al. [19], Chao et al. [5], Guo [14] and Kaya and Özer [17]. However, neither of these articles includes the effect of quality competition or cooperation.

Besides quality, from the perspective of non-price competition in the supply chain channel, other competitive factors such as service and delivery time have been studied in the literatures. For instance, Tsay and Agrawal [29] developed a general price and service competition model in a distribution channel consists of a manufacturer

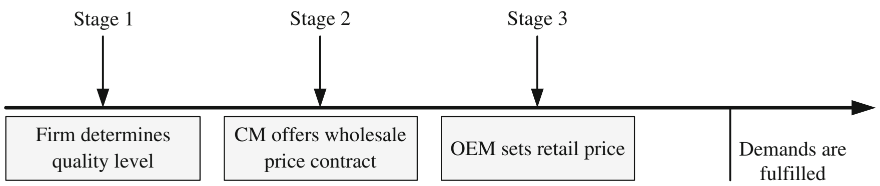

Fig. 67.1 Decision events sequence of the CM-OEM supply chain

and two competitive retailers. Xiao and Yang [32] extended this model into two competing supply chains and considered the effect of uncertain demand and risk attitude of players. Boyaci and Ray [3] studied a profit-maximizing firm selling two substitutable products in a price and delivery time sensitive market. However, these articles did not consider the cooperative strategic interactions among vertical players. We refer to Lu et al. [18] for a comprehensive review on this field.

This paper is closely related to Banker et al. [2] and Kaya and Özer [17]. Banker et al. [2] employed a two-stage game theoretic model to study price and quality decision of two competitive manufacturers as well as quality cooperation between them. Our paper differs from their works in that: (1) we develop a three-stage game theoretic model and derive the equilibrium solutions of three different decision models; (2) We investigate both upstream and downstream firm's decisions in a two-echelon supply chain; (3) We focus on vertical quality cooperation between supply chain members. Kaya and Özer [17] developed a three-stage noncooperative game for analyzing quality risk from noncontractible product quality and private quality cost information in a CM-OEM supply chain. They did not consider channel structure and quality cooperation, which are mainly discussed in our works.

67.3 Problem Description and Notations

Generally speaking, for an outsourced supply chain, the CM always makes quality decision and take all the investment expenses, While the OEM focus on sales and pricing of the products and use a simple wholesale price contract for completing the transferable payment. However, we consider a CQI scheme in which the OEM can bear partial quality investment for inducing the CM's quality improvement. We firstly propose a three-stage dynamic decision framework, as Fig. 67.1 shows.

In the noncooperative quality investment scenario, the CM determines quality level at stage 1. However, if the members jointly share quality investment expenses, the CM or the OEM can determine quality level at this stage. Then, at the following stage, the CM offers a wholesale price contract to the OEM. After observing the preceding quality level and wholesale price, the OEM sets retail price at the last stage. Then market demands are fulfilled at the determined price with the chosen quality product.

Under the common knowledge assumption, this dynamic game can be solved by using the backward induction approach. We will firstly analyze the OEMs' price decision given the CM's wholesale price and the quality level, then investigate the CM's decisions given the quality level, and study the firm's quality choice at last.

In this paper, we have the following notations:

Q : the gross demands;
α : the potential market demands;
β : the demand responsiveness to retail price with $\beta > 0$;
λ : the quality responsiveness to product quality with $\lambda > 0$;
p : the retail price;
x : the product quality level with $x \geq 0$;
w : the unit wholesale price of the CM;
c : the unit production cost of the CM;
ξ : the unit variable cost to product quality level;
ρ : the unity quality investment expense with $\rho > 0$;
π_{OEM} : the OEM's profit;
π_{CM} : the CM's profit.

For the above notations, variables x, w and p are decision variables. Other variables are exogenous, which are known to all supply chain members. Furthermore, we give the following assumption.

Assumption 1 The unit variable cost to product quality level is positive, i.e. $\xi > 0$. Many literatures allow ξ to be negative [2]. However, in this paper, we assume it cannot be negative. This assumption is possible and reasonable. For example, the Foxconn-Apple supply chain is disrupted because of the increasing costs induced by the strengthen inspections.

Assumption 2 The quality investment cost function is $\rho x^2/2$, i.e., improving quality level has a diminishing return on quality expenditure. It is commonly seen in the extant literature [2, 17, 35].

From Banker et al. [2], we assume that the OEM's gross demand not only depends on his retail price, but also depends on the product quality level. Thus, the demand function of the OEM can be written as:

$$Q(p, x) = \alpha - \beta p + \lambda x. \tag{67.1}$$

Since $\beta > 0$ and $\lambda > 0$, Eq. (67.1) shows that the retail price has negative impacts on the gross demand, while the product quality has positive impacts on the gross demand. It is reasonable for the majority products in practice.

67.4 The Model

We now study the CQI strategy in an outsourced supply chain, consisting of a CM and an OEM. Under the cooperative investment scenario, we consider two kinds of quality decision structure: the CM selects product quality level versus the OEM determines product quality level.

67.4.1 CM Optimally Sets Product Quality

We now begin analysis of the CQI strategy when the CM optimally sets quality at the first decision stage (Fig. 67.1). This is a case of a week OEM (whose only decision is to set his own product's retail price and commitment to share partial investment expenses occurred to the upper supplier) and a more powerful CM who jointly decide product quality level and wholesale price. In addition, we consider a proportional sharing mechanism and assume that θ denotes the CM's quality investment fraction, where $0 < \theta \leq 1$. We do not consider the case of $\theta = 0$, i.e., the CM makes quality decision without taking any expenses, which does not make any sense to our analysis and also is impossible in practice.

According to Eq. (67.1), we give the CM and OEM i's profit function as:

$$\pi_{OEM} = (p - w)(\alpha - \beta p + \lambda x) - \frac{(1-\theta)\rho x^2}{2}, \tag{67.2}$$

$$\pi_{CM} = [w - (c + \xi x)](\alpha - \beta p + \lambda x) - \frac{\theta \rho x^2}{2}. \tag{67.3}$$

We employ the back induction approach to solve this game, and derive the following results.

Proposition 67.1 *When the CM optimally sets product quality in the CQI strategy, if $\theta\rho > (\lambda - \beta\xi)^2/4\beta$, then the optimal quality level is:*

$$x^{C*} = \frac{(\alpha - \beta c)(\lambda - \beta\xi)}{4\beta\theta\rho - (\lambda - \beta\xi)^2}. \tag{67.4}$$

Proof Since π_{OEM} is strictly concave in retail price p, so we can get the optimal retail price $p^* = (\alpha + \lambda x + \beta w)/2\beta$ under the given variables x and w. Anticipating the OEM's optimal pricing behavior, the CM selects a wholesale price w to maximize profits $\pi_{CM}(p = p^*) = [w - (c + \xi x)](\alpha - \beta p^* + \lambda x) - \theta\rho x^2/2$ at stage 2. Thus, we can use the first order condition (FOC) to derive the optimal wholesale price $w^* = [\alpha + \beta c + x(\lambda + \beta\xi)]/2\beta$. Substituting w^* into the aforementioned profit function $\pi_{CM}(p = p^*)$ and calculate the second derivatives with regard to x, we have $\partial^2\pi_{CM}/\partial x^2 = [(\lambda - \beta\xi)^2 - 4\beta\theta\rho]/4\beta$. Thus, if $\theta\rho > (\lambda - \beta\xi)^2/4\beta$, then the π_{CM} is strictly concave in x. The optimal quality level x^{C*} follows.

In Eq. (67.4), the superscript $C*$ means it is the optimal quality value that selected by the CM in the CQI strategy. By some algebraic computation, we can derive the other equilibrium outcomes as:

$$w^{C*} = \frac{2\theta\rho(\alpha + \beta c) + (\lambda - \beta\xi)(\xi\alpha - \lambda c)}{4\beta\theta\rho - (\lambda - \beta\xi)^2},$$

$$p^{C*} = \frac{\theta\rho(3\alpha + \beta c) + (\lambda - \beta\xi)(\xi\alpha - \lambda c)}{4\beta\theta\rho - (\lambda - \beta\xi)^2},$$

$$\pi_{CM}^{C*} = \frac{\theta\rho(\alpha - \beta c)^2}{2[4\beta\theta\rho - (\lambda - \beta\xi)^2]},$$

$$\pi_{OEM}^{C*} = \frac{\rho(\alpha - \beta c)^2[2\beta\theta^2\rho - (1-\theta)(\lambda - \beta\xi)^2]}{2[4\beta\theta\rho - (\lambda - \beta\xi)^2]^2}.$$

From the above outcomes, we derive the following.

Corollary 67.1 *When the CM optimally sets product quality in the CQI strategy, the equilibrium quality, wholesale price, retail price, and profit satisfy:*

(i) $\partial x^{C*}/\partial\theta < 0$, $\partial w^{C*}/\partial\theta < 0$, $\partial p^{C*}/\partial\theta < 0$, *and* $\partial\pi_{CM}^{C*}/\partial\theta < 0$*;*

(ii) $\partial\pi_{OEM}^{C*}/\partial\theta < 0$ *for* $\theta > 1 - (\lambda - \beta\xi)^2/8\rho\beta$*;* $\partial\pi_{OEM}^{C*}/\partial\theta = 0$ *for* $\theta = 1 - (\lambda - \beta\xi)^2/8\rho\beta$*;* $\partial\pi_{OEM}^{C*}/\partial\theta > 0$ *for* $\theta < 1 - (\lambda - \beta\xi)^2/8\rho\beta$*.*

Proof Differentiating π_{OEM}^{C*} with respect to θ, we have:

$$\frac{\partial\pi_{OEM}^{C*}}{\partial\theta} = \frac{\rho(\alpha - \beta c)^2(\lambda - \xi\beta)^2[8(1-\theta)\beta\rho - (\lambda - \beta\xi)^2]}{2[4\theta\beta\rho - (\lambda - \beta\xi)^2]^3}.$$

Note that $4\theta\beta\rho - (\lambda - \beta\xi)^2 > 0$, then we have: $\partial\pi_{OEM}^{C*}/\partial\theta < 0$ for $\theta > 1 - (\lambda - \beta\xi)^2/8\rho\beta$; $\partial\pi_{OEM}^{C*}/\partial\theta = 0$ for $\theta = 1 - (\lambda - \beta\xi)^2/8\rho\beta$; $\partial\pi_{OEM}^{C*}/\partial\theta > 0$ for $\theta < 1 - (\lambda - \beta\xi)^2/8\rho\beta$. Similarly, we can show the other parts of Corollary 67.1.

Corollary 67.2 *When the CM optimally sets product quality in the CQI strategy, we have:*

(i) $x^{C*} > x^{T*}$, $\pi_{CM}^{C*} > \pi_{CM}^{T*}$*;*

(ii) $\pi_{OEM}^{C*} < \pi_{OEM}^{T*}$ *for* $\theta < \bar{\theta}$*;* $\pi_{OEM}^{C*} = \pi_{OEM}^{T*}$ *for* $\theta = \bar{\theta}$*;* $\pi_{OEM}^{C*} > \pi_{OEM}^{T*}$ *for* $\theta > \bar{\theta}$*. Where* $\bar{\theta}$ *is:*

$$\bar{\theta} = \frac{[4\rho\beta - (\lambda - \xi\beta)^2]^2 + 2\rho\beta(\lambda - \xi\beta)^2}{2\rho\beta[8\rho\beta - (\lambda - \xi\beta)^2]}.$$

Proof Subtracting π_{OEM}^{T*} from π_{OEM}^{C*}, we have:

$$\pi_{OEM}^{C*} - \pi_{OEM}^{T*} = -\frac{(1-\theta)\rho(\alpha-\beta c)^2(\lambda-\xi\beta)^2[(\lambda-\xi\beta)^4 - 2(3-\theta)\rho\beta(\lambda-\xi\beta)^2 + 16(1-\theta)\rho^2\beta^2]}{2[(\lambda - \xi\beta)^4 - 4(1+\theta)\rho(\lambda - \xi\beta)^2 + 16\theta\rho^2\beta^2]^2}.$$

By some algebraic computation, we have $\pi_{OEM}^{C*} < \pi_{OEM}^{T*}$ for $\theta < \bar{\theta}$; $\pi_{OEM}^{C*} = \pi_{OEM}^{T*}$ for $\theta = \bar{\theta}$; $\pi_{OEM}^{C*} > \pi_{OEM}^{T*}$ for $\theta > \bar{\theta}$. Similarly, we can show the other part of Corollary 67.2.

Corollary 67.1 analyzes how the decision variables are affected by the proportion coefficient θ. Corollary 67.1 means that the increase of the CM's investment sharing will definitely lower the CM's wholesale price and performance such that she would like to decrease the quality level to make a relatively higher profit. The OEM will lower the unit price to correspond to the decreased product quality which incurred by the relatively high investment proportion. However, the optimal profits of the OEM will increase in the CM's quality investment sharing if θ is sufficiently small. Otherwise, it will also decrease in θ such the situation that increasing proportion coefficient will be undoubtedly harmful to the supply chain.

Corollary 67.2 shows the effect of the CQI strategy on the supply chain member's profit, as well as the product quality. Due to the fact that partial quality investment undertaking in the cooperation schedule, the CM will be certain to benefit from cooperation, i.e., the optimal profits are strictly larger than without cooperation. However, as to the OEM, it is a fact only when the proportion coefficient is sufficient large. Otherwise, the OEM will be hurt by quality cooperation with the supplier. In addition, comparing with the noncooperative quality investment case, the CM will definitely improve the product quality because of the relatively small quality investment expenses.

The above conclusions verify an intuitive answer to the question is that the CQI strategy will offer high quality products and therefore is beneficial to the CM. Under the assumption of the CM completely controls quality decision in CQI, we show that the CM is certain to enhance product quality so as to obtain more profits. Furthermore, if the CM can share sufficiently large quality investment expenses, the OEM will also be better from quality cooperation, which means this strategy realizes a win-win situation in the supply chain.

67.4.2 OEM Optimally Sets Product Quality

In this case, we assume the OEM derives the full power to decide product quality at stage 1 (as Fig. 67.1 shows). Many literature found that lots of quality risk events which happened in outsourced supply chain in practice, e.g., the massive pet food recalls in both the US and Canada in 2007, are caused by asymmetric quality cost information between the CM and OEM [17]. However, we do not intend to investigate the effect of quality cost information asymmetry on supply chain's decision. Moreover, we assume all information is symmetric and focus on how the OEM makes quality decision.

Since the OEM optimally sets product quality level in this scenario, so we constituting the equilibrium retail and wholesale price which are calculated by the FOC into the OEM's profit function as Eq.(67.3) shows. Then the following proposition is derived.

Proposition 67.2 *When the OEM optimally sets product quality in the CQI strategy, if* $(1-\theta)\rho > (\lambda - \beta\xi)^2/8\beta$, *then the optimal quality level is:*

$$x^{O*} = \frac{(\alpha - \beta c)(\lambda - \beta\xi)}{8(1-\theta)\beta\rho - (\lambda - \beta\xi)^2}. \tag{67.5}$$

Proof Straightforward and, therefore, omitted.

In Eq. (67.4), the superscript $O*$ means it is the optimal quality value that selected by the OEM in the CQI strategy. By some algebraic computation, we can derive the other equilibrium outcomes as:

$$\begin{aligned}
w^{O*} &= \frac{4(1-\theta)\rho(\alpha + \beta c) + (\lambda - \beta\xi)(\xi\alpha - \lambda c)}{8(1-\theta)\beta\rho - (\lambda - \beta\xi)^2},\\
p^{O*} &= \frac{2(1-\theta)\rho(3\alpha + \beta c) + (\lambda - \beta\xi)(\xi\alpha - \lambda c)}{8(1-\theta)\beta\rho - (\lambda - \beta\xi)^2},\\
\pi_{CM}^{O*} &= \frac{\rho(\alpha - \beta c)^2[16\rho\beta(1-\theta)^2 - \theta(\lambda - \beta\xi)^2]}{2[8(1-\theta)\beta\rho - (\lambda - \beta\xi)^2]^2},\\
\pi_{OEM}^{O*} &= \frac{\rho(1-\theta)(\alpha - \beta c)^2}{2[8(1-\theta)\beta\rho - (\lambda - \beta\xi)^2]^2}.
\end{aligned}$$

Thus, we derive the following corollaries.

Corollary 67.3 *When the OEM optimally sets product quality in the CQI strategy, the equilibrium quality, wholesale price, retail price, and profit satisfy:*

(i) $\partial x^{O*}/\partial\theta > 0$, $\partial w^{O*}/\partial\theta > 0$, $\partial p^{O*}/\partial\theta > 0$, *and* $\partial\pi_{OEM}^{O*}/\partial\theta > 0$;

(ii) $\partial\pi_{CM}^{O*}/\partial\theta < 0$ *for* $\theta > 3/5 + (\lambda - \beta\xi)^2/400\rho\beta$; $\partial\pi_{CM}^{O*}/\partial\theta = 0$ *for* $\theta = 3/5 + (\lambda - \beta\xi)^2/400\rho\beta$; $\partial\pi_{CM}^{O*}/\partial\theta > 0$ *for* $\theta < 3/5 + (\lambda - \beta\xi)^2/400\rho\beta$.

Proof Similarly as the proof of Corollary 67.1.

Corollary 67.4 *When the OEM optimally sets product quality in the CQI strategy, we have:*

(i) $x^{O*} > x^{T*}$ *for* $\theta > 1/2$; $x^{O*} = x^{T*}$ *for* $\theta = 1/2$; $x^{O*} < x^{T*}$ *for* $\theta < 1/2$.

(ii) $\pi_{CM}^{O*} > \pi_{CM}^{T*}$ *for* $\max(0, \theta_-) < \theta < \min(\theta_+, \widehat{\theta})$; $\pi_{CM}^{O*} > \pi_{CM}^{T*}$ *for* $\theta = \theta_-$ *or* $\theta = \theta_+$; $\pi_{CM}^{O*} < \pi_{CM}^{T*}$ *for* $0 < \theta < \max(0, \theta_-)$ *or* $\min(1, \theta_+) < \theta < \widehat{\theta}$.

(iii) $\pi_{OEM}^{O*} < \pi_{OEM}^{T*}$ *for* $\theta < \breve{\theta}$; $\pi_{OEM}^{O*} = \pi_{OEM}^{T*}$ *for* $\theta = \breve{\theta}$; $\pi_{OEM}^{O*} > \pi_{OEM}^{T*}$ *for* $\theta > \breve{\theta}$.

Parameters θ_-, θ_+, $\widehat{\theta}$ *and* $\breve{\theta}$ *are:*

$$\theta_{\mp} = \frac{12\rho\beta + (\lambda - \xi\beta)^2 \mp \sqrt{(\lambda - \xi\beta)^4 - 40\rho\beta(\lambda - \xi\beta)^2 + 144\rho^2\beta^2}}{32\rho\beta},$$

$$\widehat{\theta} = \frac{8\rho\beta - (\lambda - \xi\beta)^2}{8\rho\beta}, \quad \breve{\theta} = \frac{6\rho\beta - (\lambda - \xi\beta)^2}{8\rho\beta - (\lambda - \xi\beta)^2}.$$

Proof Similarly as the proof of Corollary 67.2.

Contrary to Corollary 67.1, 67.3 implies that the increase of the CM's investment sharing will definitely improve equilibrium product quality, wholesale price, retail price and the OEM's optimal profits when product quality is set by the OEM. But it is true for the CM's optimal profits only if the OEM agrees to share sufficiently large investment expenses, i.e., θ is sufficiently small. Since in the cooperation scenario, the OEM has complete control on product quality decision without taking full responsible for all quality investment expenses. Therefore, if the CM shares more investment expenses, the OEM will be certain to improve the product quality so as to obtain higher profits.

About the effects of the CQI strategy on the player's payoff in this scenario, Corollary 67.4 shows that a fixed proportional coefficient θ, there exists some uncertainties of the relationships between with and without cooperation. Result (i) provides an interesting insight that if the quality investment expenses are equally shared between two players, the OEM will optimally sets product quality as the noncooperative case. Moreover, if the CM agrees to share more than fifty percent of the quality expenses, the CQI strategy will enhance product quality; whereas if the OEM takes more than fifty percent share, she will definitely lower product quality. Besides, part (iii) intuitively shows that if the CM's shares of quality expenses are sufficient large, the OEM will benefit from the quality cooperation. For the CM's earns, Corollary 67.4 shows more complicate results. It means that only when the proportional coefficient θ exists in a special interval, i.e., $[\theta_-, \theta_+]$, the CM can obtain more profits with cooperation.

Proposition 67.3 *Considering the optimal results of the cases of the CM and OEM optimally set product quality, we have:*

(i) $x^{C*} < x^{O*}$ *for* $\theta > 2/3$; $x^{C*} = x^{O*}$ *for* $\theta = 2/3$; $x^{C*} > x^{O*}$ *for* $\theta < 2/3$.
(ii) $\pi^{C*}_{CM} > \pi^{O*}_{CM}$, $\pi^{C*}_{OEM} < \pi^{O*}_{OEM}$.

Proposition 67.3 implies that each players in supply-chain is always better off as a quality decision maker. It means that both supply-chain members will fight for the power of quality decision under the CQI strategy, i.e., a conflict induced by quality decision may exist in the CM-OEM supply chain. Heesse [16] established a mathematical model to prove the conflict which incurred by retailer's store bands of a manufacturer–retailer supply chain, whose manufacturer optimally sets product quality and wholesale price while the retailer chose the optimal quality level of its store band and both products' retail price. Furthermore, Groznik and Heese [13] investigated the value of wholesale price commitment to this conflict. Different from these literature, Proposition 67.3 prove that even for one product quality decision, there may exist a decision conflict due to the implementation of CQI strategy in the supply chain.

67.5 Supply Chain Performance

We now begin to analyze the effect of quality cooperation on supply-chain performance. According to Lariviere and Porteus (2001), we employ the efficiency the decentralized system, i.e., the fraction of possible profit the decentralized system attains, to measure the performance of the CM-OEM supply chain. Assuming e denotes the supply-chain efficiency, we have the following result.

Proposition 67.4 *Let*

$$\theta_1 = \frac{8\rho\beta - (\lambda - \xi\beta)^2}{16\rho\beta - 3(\lambda - \xi\beta)^2}, \theta_2 = \frac{24\rho\beta - 5(\lambda - \xi\beta)^2}{32\rho\beta - 6(\lambda - \xi\beta)^2}, \theta_3 = \frac{8\rho\beta + (\lambda - \xi\beta)^2}{16\rho\beta}.$$

When $\theta_1 < \theta < \theta_2$, the CQI strategy will always improve the supply chain efficiency no matter who decide product quality, especially if $\theta_1 < \theta < \theta_3$, then $e^{O*} > e^{C*} > e^{T*}$; otherwise if $\theta_3 < \theta < \theta_2$, then $e^{C*} > e^{O*} > e^{T*}$.

Proof Assuming π_I denotes the integrated channel profits, we have: $\pi_I = [p-(c+\xi x)](\alpha - \beta p + \lambda x) - \frac{\rho x^2}{2}$. The Hessian matrix is:

$$H = \begin{bmatrix} -2\beta & \lambda + \xi\beta \\ \lambda + \xi\beta & -(\rho + 2\lambda\xi) \end{bmatrix}.$$

Assuming $2\rho\beta > (\lambda - \xi\beta)^2$, we derive the optimal integrated profits π_I^* as:

$$\pi_I^* = \frac{\rho(\alpha - \beta c)^2}{2[2\rho\beta - (\lambda - \xi\beta)^2]}.$$

Thus, we can calculate the supply-chain efficiency by:

$$e^{T*} = \frac{\pi_{CM}^{T*} + \pi_{OEM}^{T*}}{\pi_I^*}, \quad e^{C*} = \frac{\pi_{CM}^{C*} + \pi_{OEM}^{C*}}{\pi_I^*}, \text{ and } e^{O*} = \frac{\pi_{CM}^{O*} + \pi_{OEM}^{o*}}{\pi_I^*}.$$

Therefore, we can prove this proposition by some algebraic computation.

Proposition 67.4 shows the CQI strategy can improve the supply-chain efficiency through correctly determines how to share the investment expenses between the CM and the OEM. In addition, we know that the parameter θ can also be used to adjust the division of supply chain profits so as to encourage the individuals to improve product quality, which is the original intention of the CQI strategy.

67.6 Conclusions

Motivating by some supply chain quality management practices in the real world, we propose a simple proportional schedule for sharing quality investment expenses in outsourcing of a two-echelon supply chain that consists of a single CM and a single OEM. By using a three-stage dynamic game theoretic framework, we describe strategic interactions of the supply chain under two different decision structure, i.e., the CM or the OEM optimally sets product quality. We derive the rather simple analytical equilibrium results and analyze the effects of sharing coefficient on quality improvement and members' profits, as well as the supplychain performance Furthermore, we explicitly put forward the conditions on determining when the CQI strategy is beneficial to quality and profit enhancement. These results will be helpful to effectively implementing the CQI strategy in practice. This paper also provides valuable insights into the cooperative mechanism that leads to quality enhancement for supply chain outsourcing.

There are several directions for future research. Firstly, this paper shows that supply-chain members might be hurt by the CQI strategy. Thus, integrating some well-known contracts (e.g., a rebate contract, a return contract, a revenue-sharing contract, etc.) into vertical quality cooperation for designing incentives mechanism may be worth of investigating. Secondly, we assume quality investment margin of each product is common knowledge in this study. However, quality effort costs may be private information. It is interesting but challenging to investigate how the OEM designs incentive mechanisms that induce the CM to reveal his private information.

Acknowledgments We would like thank the anonymous referee and the editor for their helpful suggestions and insightful comments, which have significantly improved the content and presentation of this paper. This work was supported by the National Natural Science Foundation of China (No. 71301062) and the National Social Science Foundation of China (No. 10CGL025).

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Chapter 68
A Fuzzy Relationship Model of FMEA for Quality Management in Global Supply Chains

Lu Gan and Can Ding

Abstract In global supply chain (GSC), "agility" and continuous change are regarded as important characteristics. Dynamic alliances (DA) as a form of GSC came into being to reply to these characteristics which should be taken into account. In order to solve those potential problems that might emerge when various chain nodes are implemented, the basic and important procedures under different implementation circumstances, a fuzzy relation model of failure modes and effects analysis (FMEA) is introduced in this paper to develop quality management in DA of GSC. A solution method with Identification Algorithm Based on Genetic Algorithm (IABGA) is proposed to obtain the solution of the proposed model.

Keywords Dynamic alliance · Global supply chain · Quality management · FMEA · Fuzzy relation model · Genetic algorithm

68.1 Introduction

In this new millennium, of a developed markets, the supply chain is no longer made up in a simple form with original suppliers, services and customers, but is composed in a multi-layered, cross-regional and has even become international with chain nodes emerging as global supply chains (GSC) [2, 17]. In these circumstances, the supply chain has evolved into complex systems that rely upon highly integrated global sources with a multi-site assembly and a variety of distribution systems. Therefore, GSC has become a regime that has to be "agile" to rely upon a myriad of suppliers, in

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_68,

which dynamic alliances (DA) are created (operated and dissolved) rapidly, based on substitutable chain nodes that are put in place to service a volatile market, and then reconstituted to serve another market once demand has been foreseen, even though it is somewhat unpredictable [8, 13]. This is clearly the case with these industries such as large-scale cross-regional construction, automobile, computer, apparel and many other manufacturing industries [18].

As compared to the earlier emphasis on inspection and quality control, currently, Total Quality Management and popular Six Sigma Management Approach is being emphasized. Total Quality Management can actually be used to design and operate processes to assure supply chain quality. The central theme of quality movement - that higher quality can be attained at lower cost by Total Quality Management [9]. Furthermore, total quality management was used to establish a practical framework for strategic alliance in GSC [11]. With the advancement of research, the Six Sigma Management Approach came into being in order to suit the newer and higher demands of quality management. This approach which emerged in the 1990s has became rapidly fashionable all over the world due to its a highly-evaluated performance when it was applied into GE, Motorola and other top companies. It was also brought into quality management in GSC by some researches [1]. Besides these typical quality management methods combined into quality management in GSC, others such as computer-integrated framework were also proposed to promote development in this field [4]. As previously mentioned, in actual implementation, such as "agility" and continuous change are important characteristics in DA of GSC which should be taken into account indeed. However, earlier research has covered little to do with these referred characteristics (e.g. a quality management system applied with ISO 9001:2000 was developed for a virtual enterprise [12]). Here, virtual enterprise can be regarded as a concrete form in DA of GSC [7]. But, these are quite far removed from needs in the actual implementation, which desiderates many new theoretical paradigms and methods, especially concrete implementation tools. Additionally, with a view to the long-term development of GSC, a pre-achieved approach is needed.

In this paper, we consider the same basic and important production or technic procedures implemented by various chain nodes and engineering groups or item teams within or not of different enterprise nodes, and the potential problems which might emerge when implemented in each different life cycle of DA of GSC time after time. In order to mitigate burdens and to express such a high-risk and complicated environment, a fuzzy relationship model of failure modes and effects analysis (FMEA) is proposed in this paper. Here, the modeling and solving of the above descriptive circs is a new area of research interest. To the best of the author's knowledge, little research has been done about such problems in the actual implementation of DA in GSC. Our purpose in this paper is to make some contribution to the discussion of this new area of research. We apply the tool, FMEA, in the Six Sigma Management Approach to solve potential problems that might emerge when the same basic and important production or technic procedures are implemented by different chain nodes and engineering groups or item teams within or not of different enterprise nodes in every different life cycle of DA of GSC [3]. Through FMEA, we can identify the failure mode (i.e. potential problem) of different implementers in every different life cycle in DA of GSC and risk priority number (RPN), thus effectual advice can be obtained [5]. In order to tackle the burden of repeated work, we use historical data to get the fuzzy relationship model and then get the forecasted value through the model in the most important tache of FMEA. Here, the fuzzy relationship model play an effectual role in expressing this high-risk and complicated environment. Meanwhile, forecasted results from fuzzy relation rules are given out as the failure mode and its severity. In order to refine fuzzy relation rules by fuzzy consequence, get the forecasted results and to make the self-tuning and dynamic update mechanism more automatic, convenient and efficient, an IABGA was proposed. Thus, involving these forecasted results, the whole process of FMEA can work out the potential problems and advices to ameliorate the implementers in every different life cycle of DA of GSC, so that effectual measures can be take out previously. Finally, we can assure the quality and achieve higher quality management in DA of GSC.

The remainder of this paper is organized as follows: Sect. 68.2 states the characteristics in DA of GSC and describe the proposed problem in detail. In Sect. 68.3, we propose a fuzzy relationship model of FMEA for this problem. In Sect. 68.4, a solution method with an IABGA is proposed in order to refine fuzzy relation rules by fuzzy consequence, to obtain the forecasted results and to make the self-tuning and dynamic update mechanism more automatic, convenient and efficient. Finally, concluding remarks are outlined in Sect. 68.5.

68.2 Problem Statement

The problem considered in this paper focuses on how to identify and advise on potential problems which might emerge when the same basic and important production or technic procedures are implemented by implementers in every different life cycle of DA of GSC. This is an important agent point in actual implementation which emphasizes on the solvation of the potential problems beforehand, but remedy afterwards.

68.2.1 Brief Description for DA of GSC

DA appears to the adaptive of the characteristics of "agility" and continuous change in GSC. As we know, a supply chain is a network which is composed of several enterprises as chain nodes. Along with the volatile market, DA are created, operated, dissolved, and then reconstituted rapidly time and time again to serve an aimed at market once demand has been foreseen. In a whole life cycle of DA, several enterprises all work together for procurement, production, delivery, and other functions.

68.2.2 Brief Description for FMEA in DA of GSC

The tool, FMEA, is able to promote deep-seated improvements in the quality of design, manufacture and service procedures, as an effectually technique of reliable analysis beforehand. The main items included are as follows [14]:

- Preparation: collect correlative materials.
- Identify the possible failure modes (i.e. potential problems).
- Evaluate the possible aftereffects and the severity of each failure mode separately.
- Evaluate factors of origin and the probability of occurrence of each failure mode separately.
- Search for the manipulative factors to mitigate each failure mode and confirm the controllability as detection separately.
- Calculate the risk priority number (RPN).
- Advise on how to prevent the most harmful failure modes.
- Conclude analysis result.

Summarizing the above, we use the fuzzy relation model to identify the failure modes and severity as forecasted results, then implement the whole FMEA combined with the identify result of the fuzzy relation model to establish an integrated fuzzy relation model of FMEA to achieve the goal of quality assurance and improve quality management in DA of GSC.

68.3 Modeling

1. Failure Modes and Severity

Based on sufficient preparation, the first and most important phase in FMEA is the identification of failure modes and their severity. A fuzzy relation model obtained from historical data with a self-tuning and dynamic update mechanism can be predictive when a certain input occurs. Here, we regard the historical data of each of the chain nodes and engineering groups or item teams within or not of different enterprises implementing the aimed at process in every different life cycle of DA of GSC as the data of one period. Considering the input and out put item, we can confirm by type according to the the qualification of the implementers and the product or service process, that can avoid un-occurrence and iterance (Table 68.1).

(1) Fuzzify the Input and Out Data

We divide the boundary of [0, 10] of input and output data into 10 grades and define each as G_k like below: $G_k \triangleq [k-1, k]$.

Table 68.1 Standard of evaluation for input and output items

Input											
Qualification level	Fearfully excellent	Quite excellent	Excellent	Quite well	Well	Medium	Not good	Quite not good	Bad	Worse bad	Unqualified
Value	10	9	8	7	6	5	4	3	2	1	0
Output											
Harm of aftereffects	Serious without a alarm	Serious with a alarm	Very high	High	Medium	Low	Very low	Slight	Very slight	Fearfully slight	None
Value	10	9	8	7	6	5	4	3	2	1	0

$$\mu_1(x)=\begin{cases}1, & \text{if } 0\le x\le 0.75\\ \frac{x-1.5}{0.75-1.5}, & \text{if } 0.75\le x\le 1.5,\end{cases}\quad \mu_2(x)=\begin{cases}\frac{x-0.5}{1.25-0.5}, & \text{if } 0.5\le x\le 1.25\\ 1, & \text{if } 1.25\le x\le 1.75\\ \frac{x-2.5}{1.75-2.5}, & \text{if } 1.75\le x\le 2.5,\end{cases}$$

$$\mu_3(x)=\begin{cases}\frac{x-1.5}{2.25-1.5}, & \text{if } 1.5\le x\le 2.25\\ 1, & \text{if } 2.25\le x\le 2.75\\ \frac{x-3.5}{2.75-3.5}, & \text{if } 2.75\le x\le 3.5,\end{cases}\quad \mu_4(x)=\begin{cases}\frac{x-2.5}{3.25-2.5}, & \text{if } 2.5\le x\le 3.25\\ 1, & \text{if } 3.25\le x\le 3.75\\ \frac{x-4.5}{3.75-4.5}, & \text{if } 3.75\le x\le 4.5,\end{cases}$$

$$\mu_5(x)=\begin{cases}\frac{x-3.5}{4.25-3.5}, & \text{if } 3.5\le x\le 4.25\\ 1, & \text{if } 4.25\le x\le 4.75\\ \frac{x-5.5}{4.75-5.5}, & \text{if } 4.75\le x\le 5.5,\end{cases}\quad \mu_6(x)=\begin{cases}\frac{x-4.5}{5.25-4.5}, & \text{if } 4.5\le x\le 5.25\\ 1, & \text{if } 5.25\le x\le 5.75\\ \frac{x-6.5}{5.75-6.5}, & \text{if } 5.75\le x\le 6.5,\end{cases}$$

$$\mu_7(x)=\begin{cases}\frac{x-5.5}{6.25-5.5}, & \text{if } 5.5\le x\le 6.25\\ 1, & \text{if } 6.25\le x\le 6.75\\ \frac{x-7.5}{6.75-7.5}, & \text{if } 6.75\le x\le 7.5,\end{cases}\quad \mu_8(x)=\begin{cases}\frac{x-6.5}{7.25-6.5}, & \text{if } 6.5\le x\le 7.25\\ 1, & \text{if } 7.25\le x\le 7.75\\ \frac{x-8.5}{7.75-8.5}, & \text{if } 7.75\le x\le 8.5,\end{cases}$$

$$\mu_9(x)=\begin{cases}\frac{x-7.5}{8.25-7.5}, & \text{if } 7.5\le x\le 8.25\\ 1, & \text{if } 8.25\le x\le 8.75\\ \frac{x-9.5}{8.75-9.5}, & \text{if } 8.75\le x\le 9.5,\end{cases}\quad \mu_10(x)=\begin{cases}\frac{x-8.5}{9.25-8.5}, & \text{if } 8.5\le x\le 9.25\\ 1, & \text{if } 9.25\le x\le 10.\end{cases}\tag{68.1}$$

If

$$\mu_{F_s}(I_{mt})=\max\left[\mu_{F_1}(I_{mt}),\mu_{F_2}(I_{mt}),\cdots,\mu_{F_S}(I_{mt})\right]\tag{68.2}$$

then I_{mt} is attribute to F_s denoted as $F(I_{mt})$, $\mu(I_{mt})=\mu_{F(I_{mt})}(I_{mt})$.
If

$$\mu_{F_s}(O_{nt})=\max\left[\mu_{F_1}(O_{nt}),\mu_{F_2}(O_{nt}),\cdots,\mu_{F_S}(O_{nt})\right]\tag{68.3}$$

then O_{nt} is attribute toF_s denoted as $F(O_{nt})$, $\mu(O_{nt})=\mu_{F(O_{nt})}(O_{nt})$.

Then, we set 10 fuzzy sets based on these 10 grades and confirm the membership functions for each fuzzy set. Here, we use a trapezoidal fuzzy variable as in (68.1), which can be used to properly describe the fuzzy attributes of the evaluation value [10].

Based on the membership functions of fuzzy sets in (68.1), we can decide the certain fuzzy sets to which the input and output item variables (e.g. I_{mt}, O_{nt}) are attributed and their memberships, shown in Eqs. (68.2) and (68.3).

(2) Confirm the Configuration of Fuzzy Relation Model

Fuzzy relation model is a forecast model which produces the forecast value of output items from the input item value through a series fuzzy relation rules in a configuration composed by confirmed input and output item variables obtain by correlation analysis. Therefore, to confirm the configuration of input and output item variables is mainly depended on the correlation analysis. Besides, our model system of identification has a with multi-input and multi-output, thus, confirmation of the configuration is refined for each aimed at output item variable with all input item variables in our fuzzy relation model. Furthermore, time lag is a configurable factor which can not be ignored. As a result, our correlation analysis aims to analyze the relativity of each output item variable, itself and all input item variables considering time lag. So, the confirmation configuration is shown in (68.4).

$$\begin{aligned}&[I_{1(t-a)}, \cdots, I_{m(t-a)}, \cdots, I_{M(t-a)}, O_{n(t-b)}, O_{nt}],\\ &\quad a = 1, 2, \cdots, A, \quad b = 1, 2, \cdots, B, \quad n = 1, 2, \cdots, N.\end{aligned} \tag{68.4}$$

We choose quality-related analysis to confirm the relativity of each output item variable, itself and all input item variables and consideration time lag using the fuzzy set indexes which each input and output item variables are attributed to for all periods as the analysis data [15, 16]. The results of the correlated analysis gives out the available input item variables which may be composed of original input items variables of current period, original input items variables of the time lag period and original output items variables of the time lag period. We define the newly composed input items as x_{lt} with the index l denoting the l input item variable and the index t denoting the t period.

(3) Confirm Fuzzy Relation Rules

Based on the confirmed configuration with each output, itself and all inputs with the consideration of time lag, we can get the fuzzy rules of how to forecast the output item variable of each with certain input item variables. Here, through correlation analysis, we can use available input item variables which are relative to the output item variables being under consideration.

The obtain of the fuzzy relation rules for each output item variable is shown below.

Step 1. Calculate the possibility distribution of all input and each output data on all fuzzy sets of the t period as in (68.5).

$$\begin{cases} p_{lts} \triangleq \text{poss}(F_s|x_{lt}) = \sup\min[F_s(x_{lt}), \mu(x_{lt})],\\ l = 1, 2, \cdots, L, \quad s = 1, 2, \cdots, S\\ p_{nts} \triangleq \text{poss}(F_s|O_{nt}) = \sup\min[F_s(O_{nt}), \mu(O_{nt})],\\ n = 1, 2, \cdots, N, \quad s = 1, 2, \cdots, S.\end{cases} \tag{68.5}$$

Here, $\mu(x_{lt})$ is the membership function of x_{lt} on the set which it is attributed to, and $\mu(O_{nt})$ is the membership function of O_{nt} on the set which it is attributed to.

Step 2. Conformation vector to $t = 1, 2, \cdots, T$ as in (68.6).

$$\begin{cases} p_{lt} = [p_{lt1}, \cdots, p_{lts}, \cdots, p_{ltS}],\ l = 1, 2, \cdots, L \\ p_{nt} = [p_{nt1}, \cdots, p_{nts}, \cdots, p_{ntS}],\ l = 1, 2, \cdots, n. \end{cases} \tag{68.6}$$

Step 3. Conformation the fuzzy relation rules R_{nt} for the n output item variable using data of the t period in (68.7).

$$R_{nt} = p_{1t} \times \cdots p_{lt} \times \cdots p_{Lt} \times p_{nt}, \quad n = 1, 2, \cdots, N. \tag{68.7}$$

Here, $\times$ denotes the Descartes operation as shown in (68.8).

$$\begin{aligned} &R_{nt}(1_r, \cdots, l_r, \cdots, L_r, n_r) = \min[p_{1t1_r}, \cdots, p_{ltl_r}, \cdots, p_{LtL_r}, p_{ntn_r}] \\ &\quad 1_r, \cdots, l_r, \cdots, L_r, \quad n_r = 1, 2, \cdots, S, \quad n = 1, 2, \cdots, N. \end{aligned} \tag{68.8}$$

Here, we use the max-min operator, and $1_r, \cdots, l_r, \cdots, L_r, n_r = 1, 2, \cdots, S$ denotes the dimensions of Descartes operation.

Step 4. Calculate the integrated fuzzy relation rules of the n output item variable as in (68.9):

$$\begin{aligned} &R_n = \bigcup_{t=1}^{T} R_{nt} \\ &\text{i.e. } R_n(1_r, \cdots, l_r, \cdots, L_r, n_r) = \bigvee_{t=1}^{T} R_{nt}(1_r, \cdots, l_r, \cdots, L_r, n_r) \\ &\quad 1_r, \cdots, l_r, \cdots, L_r, \quad n_r = 1, 2, \cdots, S, \quad n = 1, 2, \cdots, N. \end{aligned} \tag{68.9}$$

(4) Forecast Output

When the fuzzy relation rules R_n for the n output item variables are known, then obtain the forecast value of output item variables is shown below.

Step 1. Find the most adjacent fuzzy set of each newly input item variable $x_{lt},\ l = 1, 2, \cdots, L$ in period t, denote as $F_{lt\lambda_l}$, thereinto, shown as in: $\lambda_l = \{s | p_{lts} > q,\ \ s = 1, 2, \cdots, S\}, l = 1, 2, \cdots, L$. Here, $0 < q < 1$ is a value set beforehand.

Step 2. If λ_l is separately exclusive, the forecast fuzzy sets for which the output item variables are attribute to are as shown in (68.10):

$$\begin{aligned} &\overline{F}_{O_{nt}} = \max_{n_s} \min[R_n(\lambda_1, \cdots, \lambda_l, \cdots, \lambda_L, n_s), \mu(O_{nt})] \\ &\quad n = 1, 2, \cdots, N, \quad n_s = 1, 2, \cdots, S. \end{aligned} \tag{68.10}$$

If λ_l is not exclusive, denote these as $\lambda_1^{(1)}, \cdots, \lambda_l^{(e)}, \cdots, \lambda_L^{(E)}$, then, (68.10) changed into (68.11):

$$\overline{F}_{O_{nt}} = \max_{\lambda_1^{(e)}} \cdots \max_{\lambda_l^{(e)}} \cdots \max_{\lambda_L^{(e)}} \max_{n_s} \min[R(\lambda_1, \cdots, \lambda_l, \cdots, \lambda_L, n_s), \mu(O_{nt})] \quad l = 1, 2, \cdots, L, \quad \lambda_l = \lambda_l^{(1)}, \cdots, \lambda_l^{(e)}, \cdots, \lambda_l^{(E)}, \quad n = 1, 2, \cdots, N, \quad n_s = 1, 2, \cdots, S. \tag{68.11}$$

Step 3. Use the halved point of the area which the membership function of the forecasted fuzzy set has covered as the forecasted value of the output item variable denoted as $\overline{O}_{nt}$.

(5) Check Validity

After the fuzzy relation rules have been obtain, checking the validity of these rules is necessary. Average variance of the actual evaluation value and the forecast value for the n output item variable is proposed here to do the work as in (68.12):

$$P_n = \frac{1}{T} \sum_{t=1}^{T} (O_{nt} - \overline{O}_{nt})^2. \tag{68.12}$$

(6) Self-tuning and Dynamic Update Mechanism

Based on the process of establishing fuzzy relation model, it is clear that it is established according to the data of input and output in a series of periods. Therefore, in order to improve the precision of the forecast, we can adjust the fuzzy relation rules in our proposed model based on the error between the actual evaluation value and the forecast value.

(7) Select Failure Modes with Severity

Based on the forecast values of the output item variables, we can select the failure modes needed for consideration. Here, we can confirm a standard (e.g. $\geq$1) regarding severity, those failure modes accord with the standard that can be selected with severity.

2. Occurrence and Probability

This phrase is to evaluate the origin factors and the occurrence of failures that also play an important role in FMEA. As referred to, to accomplish this task depends more on the a series of expert knowledge, experiments and statistical analysis of historical data, which the fuzzy relation model seems not to be suitable in the current phase for it ought to add the complexity of the work, which acts against our original intention.

3. Controllability and Detection

This phrase is to search for the mitigating manipulative factors of each failure mode and to confirm the controllable detection separately. As referred to, the same as to the occurrence, to accomplish this task depends more on the a series of expert knowledge, experiments and statistical analysis of historical data, which the fuzzy relation model seems not to be suitable for, in the current phase for it ought to add to the complexity of the work, which quite acts against our original intention.

We calculate RPN for all selected failure modes, and this reflect the degree of risk which provides an order of prevention.

4. Advice on Prevention and Rectification

Based on the RPN, it ought to advise on the most pivotal failure modes of the highest RPN with measures of prevention and rectify in order to develop quality management in DA of GSC.

5. Analysis Result

FMEA is an important method to solve the potential problems that emerge in DA of GSC when chain nodes and engineering groups or item teams within or not of different enterprises implement these basal and important production or technic procedures in every different life cycle of DA of GSC. So the obtain an analysis result formed in the table is necessary and in need for the implementer and it can provide historical data for the dynamic updating of the fuzzy relation model of FMEA.

68.4 Solution Method

In our paper, in order to refine fuzzy relation rules by fuzzy consequence, obtain the forecasted results (i.e. the failure mode and its severity) and make the self-tuning and dynamic update mechanism more automatic, convenient and efficient with a gained fuzzification and confirmed the configuration of fuzzy relation model, an IABGA was proposed. This is an algorithm based on the modeling process in our paper with multiple input and outputs, and is combined with these equivalently by simplified thoughts in a single input and output system. Thus, involving these forecasted results, the whole process of FMEA can work out the potential problems and advices to ameliorate the implementers in every different life cycle of DA of GSC. At last the analysis result can be worked.

The steps in our method for solving the problem are as follows:

Step 1. Fuzzify the input and out data to prepare for the algorithm. Here, we can get the fuzzy sets to which the data are contributed to and the memberships of the data on the very fuzzy sets as its own memberships.

Step 2. Confirm configuration of output with itself and all input with the consideration of time lag through correlation analysis based on the fuzzification results in Step 1 to get available input item variables which are relative to the output item variables under consideration.

Step 3. Use IABGA to refine fuzzy relation rules by fuzzy consequence, get the forecasted results and do the validity checking, the self-tuning and dynamic update mechanism.

Step 4. Evaluate the origin factors and the occurrence of failures is also playing an important role in FMEA.
Step 5. Search for the manipulative mitigating factors each failure mode and confirm separately the controllable as detection.
Step 6. Calculate the risk priority number, which is the product of severity, probability and detection.
Step 7. Advice on prevention and rectification Based on the RPN.
Step 8. Analysis result. Thereinto, Step 1–Step 3 of the proposed method is aimed at obtaining the failure mode with severity. These process should be done repeatedly to each output item variables with all input data.

Overall procedure of the IABGA The steps in our proposed IABGA are as follows:

Step 1. Set the initial value and parameters of the genetic algorithm: population size, pop size, crossover rate pc, mutation rate pm, and maximum generation max gen.
Step 2. Generate the initial population.
Step 3. Evaluation and Selection.
Step 4. Genetic operator: Crossover and mutation.
Step 5. Stop condition: If a pre-defined maximum generation is reached or an optimal solution is located during genetic search process, then stop; otherwise, go to Step 3. Here, we confirm that if the optimal value of adjacent two generations fixed on the same value for a pre-defined times, the stop. At this time, the algorithm is successful. Otherwise, the stop condition is to reach the pre-defined maximum generation, the algorithm is fail.
Step 6. Repeat Step 1–Step 5 with all the input data to get the completed fuzzy relation rules. This can be used to get the corresponding forecasted fuzzy set which the output item variable is attributed to with certain input item variables (these should be under fuzzify).
Step 7. Getting the fuzzy set to which the output item variable is, we use the halved point of the area which the membership function of the forecasted fuzzy set has covered as the forecasted value of the output item variable.
Step 8. Use self-tuning mechanism to adjust the fuzzy relation rules.
Step 9. Dynamic update the exited fuzzy relation rules when long-term implement.

68.5 Conclusions

In this paper, based on the consideration of the fact of the actual implementation of GSC that DA of GSC are created (operated, and dissolved) rapidly, based on substitutable chain nodes that are put in place to service a volatile market, and then reconstituted to serve another market once demand has been foreseen. This form of GSC came into being to reply to such characteristics as “agility” and continuous change of GSC which should be take into account. In order to solve potential problems that might emerge when various chain nodes implemented the basic and important procedures under different implementation circumstances, we introduce the effective tool, FMEA, in a Six Sigma Management Approach and proposed a fuzzy relation model of FMEA to develop quality management in DA of GSC for quality assurance.

Although the proposal in this paper should be helpful for solving some real world problems, detailed analysis and further research are necessary to reveal more properties of a good method for solving other related problems.

Acknowledgments This research has been supported by the Key Scientific Research Projects of Xihua University, P.R. China (Grant No. Z1321501); the General Fund Project of Sichuan Provincial Department of Education (Grant No. 14ZB0014).

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Chapter 69
Designing Lean Supply Chains: A Case Study

Karn Chantarachalee, Helena Carvalho and Virgílio António Cruz-Machado

Abstract This paper provides perspectives on how to design lean supply chains. It describes a real case study related to construction materials supply chain. In the case study is considered a supply chain setting where the dealer's have dominant bargaining power over the manufacturer. It intents to analyze the impact of this setup in overall performance in terms of lead time and how the supply chain could be designed to be more lean. First, a value stream map, a deployment flowchart and a simulation model are presented to describe the case study. Second, a lean tool, the 7-wastes, is used to analyze and redesign the supply chain configuration. Using simulation, is possible to conclude that this new configuration allows a lead time reduction. Finally the conclusions are presented, highlighting how the lean tools can be used in a real supply chain setting.

Keywords Lean · Supply chain · Lead time · Case study construction materials

69.1 Introduction

The lean paradigm is a recognized management approach. It was developed by Ohno [9] at Toyota Motor Corporation in Japan and it forms the basis of the Toyota Production System (TPS). The focus of the lean approach is on the waste reduction of increasing actual value-added to fulfill customers' needs and maintaining profits. This new structural approach and the way Toyota used lean production changed the nature of automobile manufacturing [13]. Despite the lean approach had been highly diffused in production and manufacturing context, e.g [7, 10], the expanding

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6_69,

of this management approach to the supply chain (SC) context is still not fully comprehended [4, 5].

Reichhart and Holweg [11] had extended the concept of lean production to the downstream or distribution level: "we define lean distribution as minimizing waste in the downstream SC, while making the right product available to the end customer at the right time and location". To Vonderembse et al. [12] a lean SC is the one that employs continuous improvement efforts that focus on eliminating waste or non-value steps along the chain. The internal manufacturing efficiency and setup time reduction are the enablers of the economic production of small quantities, cost reduction, profitability, and manufacturing flexibility [10]. At operational level, the lean approach in the extended SC can be implemented by using a number of tools such as value stream mapping, 7-wastes, takt time and 5S principles [5]. The application of these techniques throughout the SC has a consequence in decreasing of redundancy in materials, processing and transportation activities.

Lean is a well-known and proven method for reducing waste in a process. According to Cudney and Elrod [4] the 7-wastes of lean (overproduction, transportation, inventory, processing, waiting, motion, and defects) can also be applied to support the improvement of SC functions such as procurement, engineering, invoicing, inventory control, order entry, scheduling, accounting, and sales. However, there are some drawbacks of the lean paradigm when applied to the SC: shorter setup times provide internal flexibility, but a lean SC may lack external responsiveness to customer demands, which can require flexibility in product design, planning and scheduling, and distribution [10]. Extending lean beyond the factory and component supply system into distribution operations results in a potential conflict: the need of production smoothing and kanban systems (that cannot cope with high levels of variability) and the need to link the production pull signal to variable demand in the marketplace [7]. The lean approach has been considered to perform better when there is high volume, low variety and predictable demand with supply certainty, so that functional products can be created. Conversely, in high variety and volatile supply chains, where customer requirements are often unpredictable; a much higher level of agility is required [1, 3, 8]. However, in order to add value to the customer, the lean approach seeks to find ways to manage variability and to create capability by utilising assets more effectively than in traditional systems [6].

Lean paradigm has three objectives to be accomplished: (1) best quality; (2) reduced lead times; (3) lower cost. In this paper is presented a real case study related to construction materials SC. The objective is to illustrate how to the SC can be redesigned to become more lean and reduce waste.

69.2 Case Study Description

This section aims to describe you the real situation of a SC. Data related to the SC was obtained using one SC engineer and four SC managers of the manufacturer as informants. The focal entity is a construction materials manufacturer who

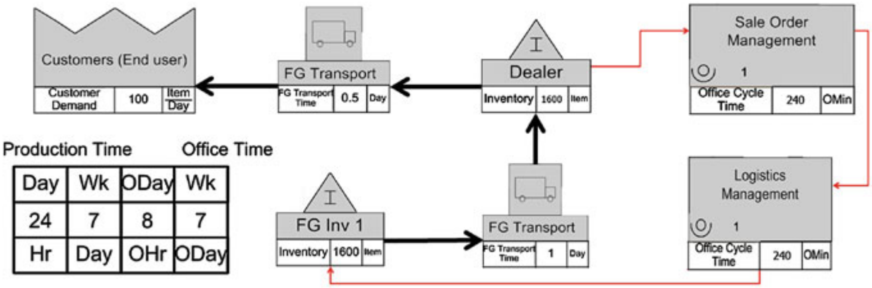

Fig. 69.1 Supply chain value stream map current state

owns the biggest market share in the roof product market in a country located in the Association of Southeast Asian Nations (ASEAN). The network description focuses on inventory level along the SC, lead time from manufacturer to end user, SC activities, and relationships among SC entities: dealer, focal company, and end-user. Figure 69.1 contains the network value stream map. To assure confidentiality of data the information collect from the company was altered, so the values presented in Fig. 69.1 are only representative of the SC behavior.

In the SC under study the end users could be individual house owners, house building contractors, or even real estate developers. The customers or end users demand is 100 items a day. End users buy products from dealers. For some big demand projects, the manufacturer has another channel to deal with end user but in major cases they still rely on their dealers.

Dealers order roof products from the manufacturer via Sale Order Management Team (SOM) then dealers can wait for product delivery. Dealers have big inventories of their own. They can buy discount products from the manufacturer and hoard up the product to sell it to end user when the price is up. Not only they have their own inventory, but also during the product ordering process they can book or reserve manufacturer inventory and then they can cancel the booked products at any times they want without any penalties. Dealers arrange their own truck fleet to deliver products to end users from their locations. Dealers can deliver their products to end users within 0.5 days after they get the customers' orders. The number of dealers' inventory locations is much more than the number of manufacturer's inventory locations. The dealers' inventories are situated closer to end user locations which could lead to faster response and higher service quality for end user's perspective.

The manufacturer SOM team receives product orders from dealers and decide how much and how many products should they fill in the orders prioritized by dealer performance among other factors. To make this decision, SOM tries to figure out how to screen and select the real demand orders from the dealers' orders. The results of this selection process, some orders are fulfilled and some are partially filled. This result makes dealers' demand more fluctuated. For example, dealers expect their product orders to be partially filled by SOM. If they want 100 product items, they will order 120 items instead, so they can get 100 items as they want. After the orders are filled

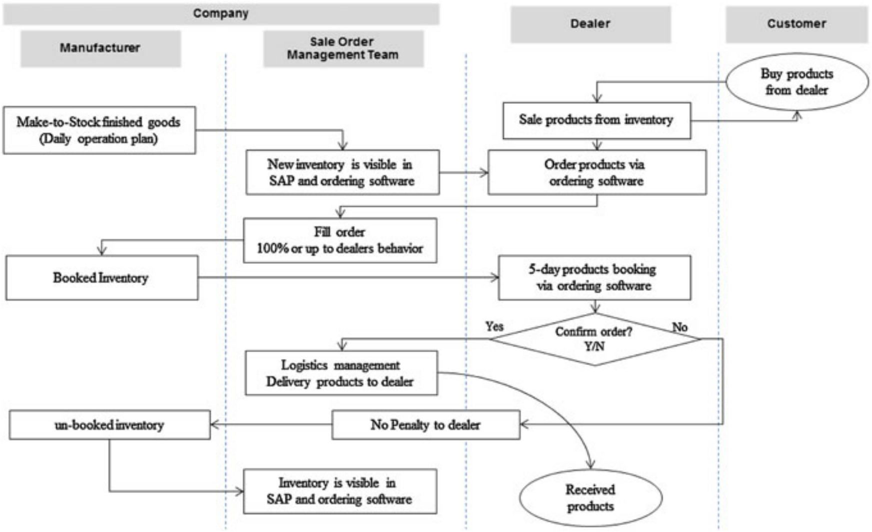

Fig. 69.2 Product ordering process deployment flowchart

by SOM, dealers will have maximum 5 days to confirm the order and commit to receive the booked products. During the 5 days, the booked orders maintain booked inventory for the manufacturer. More details of this ordering process are shown in Fig. 69.2.

End user buys a product from the dealer's inventory. The manufacturer is working on make-to-stock basis. Every day the SOM teamverifies the new available inventory on the company information system (SAP software). SOM will manipulate some critical product inventories before dealers can see new free float available products for booking via ordering software. If dealers want to refill their inventory, they will send product orders to SOM. SOM will manage inventory and decide to fill products into the orders. The manufacturer will hold booked inventory for dealers for 5 days since the booked status occurs. When dealers confirm and want to receive the booked products, logistics management team will manage the product delivery to dealers. However, if dealers don't want the booked inventory anymore, dealers can cancel the booked orders without penalty and can send new product order instantaneously. Then the booked inventories return to be free float inventory back into SAP again.

To obtain the SC performance data Arena simulation software was applied to draw up a simulation model based on Figs. 69.1 and 69.2. The simulation model output is the total lead time since manufacturer's supply to end user's demand. This performance measure was chosen because one of lean objectives is to reduce lead time; this an important indicator of wastes along the SC. The simulation model run for 30 replications, 5 years each replication. The simulation model is shown in Fig. 69.3 and considers the assumptions shown in Table 69.1.

After running the simulation model it was obtained a lead time of 18.85 days.

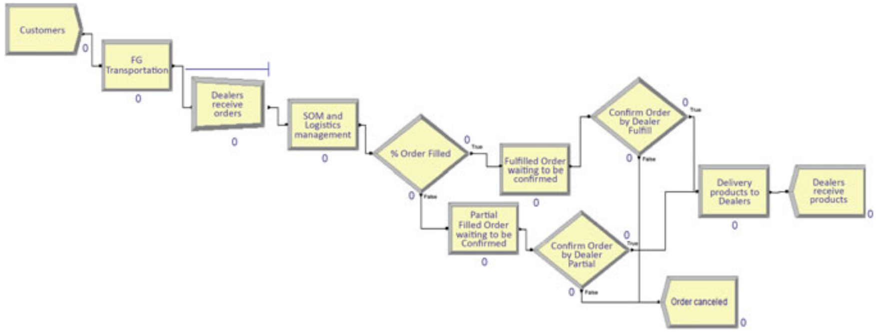

Fig. 69.3 Supply chain ordering process simulation model

Table 69.1 Simulation model assumptions

Node	Variables	Type of distribution	Parameter
Customer demand	Time between arrivals	Normal distribution	Mean: 1 day, Std: 1 day
	Entities per arrival	Normal distribution	Mean: 100 items, Std: 30 items
Finish goods transportation	Transportation time	Constant	0.5 days
SOM and logistics	Office time	Constant	1 day
Mgt. % order filled	Decision probabilities	2-way by chance	Fulfilled: 75 %, Partial: 25 %
Fulfilled order	Waiting time to confirm	Normal distribution	Mean: 1 day, Std: 0.3 days
Partial filled order	Waiting time to confirm	Normal distribution	Mean: 3 day, Std: 1 days
Confirm fulfilled order	Decision probabilities	2-way by chance	Yes: 75 %, No: 25 %
Confirm partial order	Decision probabilities	2-way by chance	Yes: 50 %, No: 50 %
Delivery product	Transportation time	Constant	1 day

69.3 Redesign the Supply Chain Using the 7-Wastes

In this section intends to describe how the SC performance can be improved using Lean tools, namely the 7-wastes.

After identifying the activities that promote wastes along the SC the eliminate, combine, reduce, and simplify the technique (ECRS) is used to show how these wastes could be managed considering only managerial issues and ignore political issues or financial issues. Table 69.2 contains the activities that promote waste along the SC under study.

Table 69.2 highlight the7-wastes that happen along the different SC activities and how they could be eliminate, combine, reduce, and simplify. This step gives indications on how to redesign a un-lean SC to create a leaner SC. The objective is to eliminate waste as much as possible based on managerial concerns. Table 69.3

Table 69.2 The wastes along the supply chain

	Activities	7 wastes							ECRS
		Over[a]	Inventory	Trans[b]	Motion	Over[c]	Delay/ waiting	Defect/ error	Eliminate[d]
1	Customers buy products from dealers			✓	✓				C, R, S
2	Dealer sale products from his inventory	✓	✓		✓	✓	✓	✓	E
3	Make-to-stock manufacturing	✓	✓	✓	✓	✓	✓	✓	R
4	Available inventory to sale order management team and Dealer					✓	✓		C, R, S
5	Dealer order refilled inventory from sale order management team					✓	✓	✓	C, R, S
6	Sale order management team decides how to match products and orders				✓	✓	✓	✓	E
7	Available inventory become booked		✓			✓	✓	✓	E
8	7-day product booking lifetime		✓		✓	✓	✓	✓	E
9	Dealer decide to accept matched orders		✓			✓	✓	✓	E
10	Products delivered to dealer		✓	✓	✓	✓	✓	✓	C, R, S
11	If dealer rejects matched orders	✓	✓			✓	✓	✓	E
12	No penalty to dealer						✓	✓	E
13	Booked inventory become available	✓	✓			✓	✓	✓	E
14	Repeat booking process	✓	✓		✓	✓	✓	✓	E

[a]Over production
[b]Transportation
[c]Over processing
[d]Eliminate/Combine/Reduce/Simplify

provides some examples of the ECRS technique application. In a multiple product SC is necessary to prioritize efforts. To this end is suggest the utilization of a Pareto chart to find out which products are more critical. It was collected data related to 1-year of delivered roof products from manufacturer to dealer in order to prioritize products performance by sale volume. By Pareto chart (Fig. 69.4), is possible to conclude that only 37.5 % of product SKUs own 80 % of sales volume.

Table 69.3 7-Wastes and ECRS technique examples

7-Wastes	Managerial issues	ECRS examples
Overproduction	(a) Requesting a quantity greater than needed form end use	Eliminate: Never decide how much to fill products in the dealer's order. It must be 100 % fulfilled all orders to discover real demand
Inventory/space	(a) Too much inventory due to early deliveries	Combine: Mutual inventory or Vendor Managed Inventory (VMI), it can make
	(b) Receiving quantity greater than needed	end user's demand more transparent,lead to less inventory buffer and pull SC by combining all players' forecasting process
Transportation/ conveyance	(a) Fast moving inventory to the back of the warehouse	
	(b) Unnecessary transport that results in added cost	
Motion	(a) Unnecessary movement of people: walking, reaching, and stretching caused by poor storage arrangement or poor ergonomic design of working areas	Reduce: Automated Storage and Retrieval system (ASRS) can increase capacity of warehouse and also reduce motions, movements and inbound transportation
Delay/waiting	(a) Waiting for a dock to clear, loading/unloading	Make-to-order product, manufacturer can focus on top performance product
	(b) Any delay within a process or between the end of one activity and the start of the next activity	with high sale volume and income. This could make top products delivered data higher service level for customers and less complicated works for suppliers
Defect/error	(a) Damage, defective, errors	
	(b) Inventory discrepancies and adjustment	
Over-processing	(a) Doing something that customer does not require	Simplify: IT infrastructure, establish new inventory information sharing
	(b) Doing things that are too complicated	system among all companies and dealers
	(c) Having unclear standards and specifications	

69.3.1 Redesigning a More Lean Supply Chain

In this step, a new SC scenario with less waste is proposed. This scenario design is based on information gathered from the application of lean tools and considering the managerial perspectives of one SC engineer and four SC managers belong to the focal company. To clarify the new SC scenario, a new value stream map, ordering process

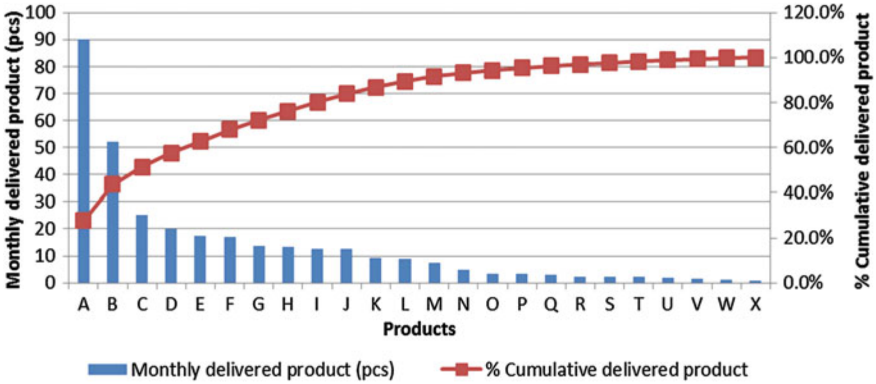

Fig. 69.4 Roof product Pareto chart by sales volume

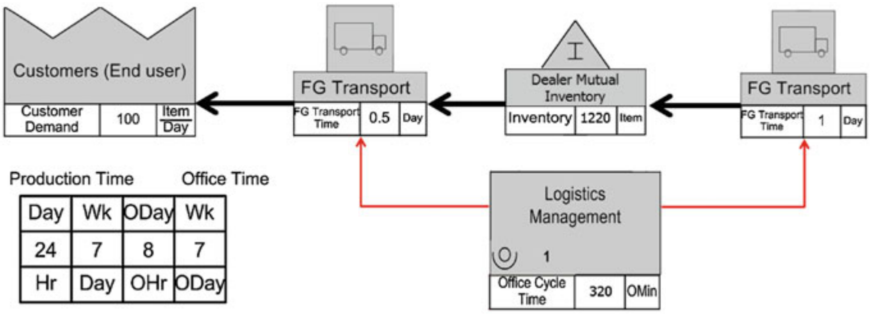

Fig. 69.5 Supply chain value stream map future state

deployment flowchart and simulation model are presented. Figure 69.5 contains the value stream map future state.

The main differences between Fig. 69.1 (current state) and Fig. 69.5 (future state) are: (1) the creation of a mutual inventory among dealers and the manufacturer; (2) the logistics management team is responsible by manage the finished goods transportation for dealers and co manufacturer; (3) all orders are 100 % fulfilled therefore the SOM is unnecessary.

According to the future state the dealers and manufacturer join their inventory in a mutual inventory. This inventory is managed like Vendor Managed Inventory (VMI) and could be 50/50 owned by manufacturers and dealers or 100 % owned by manufacturer depending on agreements. The existence of a mutual inventory will also support collaborative demand forecasting process among dealers and the manufacturer. They will have better demand visibility, less inventory buffer, and less demand fluctuation [2] in the SC.

Also, it is proposed that manufacturer own and manage 100 % truck fleet by the Logistics Management Department. So, the manufacturer will be able to provide all-in-one service to new dealers and can provide more options for old dealers to

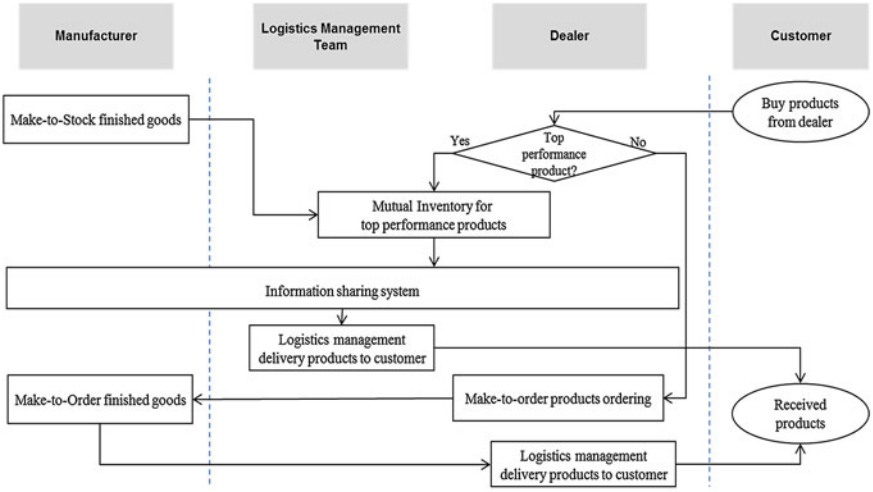

Fig. 69.6 New design of ordering process deployment flowchart

change their business operation. In the new model, dealers can be anyone who can influence end users to buy products. Big investment, good location, and effective management system are not essential requirements to be a dealer anymore. This will open the opportunity for many people to sell products from the manufacturer. The manufacturer SC managers believe that this could help balance dealer's bargaining power to be more manageable.

In the proposed scenario the sale order management (SOM) is not necessary (as mentioned in Table 69.3). Is not necessary to decide how much to fill products into dealer's order anymore. This is a non-value added activity and it manipulates fluctuated demand among dealers and manufacturer. All orders must be 100 % fulfilled. Figure 69.6 contains the new ordering process details.

Under the new design, customers can order their products from dealers by 2 options: (1) make-to-stock system for top performance products; (2) make-to-order system for low performance products. After customers order the products if it is make-to-stock product, logistics management team will arrange truck fleet to deliver product to customers within 0.5 days. And the mutual inventory will be managed and refilled automatically by the manufacturer and dealer collaborative demand forecasting system. If it is make-to-order product, customers need to wait 10 days for production lead time and 1 day for product delivery from plant to customers.

Considering the make-to-order products, it looks like a huge loss of customer service but the manufacturer and the dealers can compensate this loss by having customized agreements with end users case by case for examples: (1) help end users plan their materials requirements since the beginning of the construction process; (2) give special discount rate on make-to-order products; (3) let dealers take the risks by holding make-to-order products as their own inventory for end users.

Table 69.4 Assumptions of lean supply chain simulation model

Node	Variables	Type of Distribution	Parameter
Customer demand	Time between arrivals	Normal distribution	Mean:1 day, Std:1 day
	Entities per arrival	Normal distribution	Mean: 100 items, Std: 30 items
Finish goods transportation	Transportation time	Constant	0.5 days
SOM and logistics Mgt.	Office time	Constant	1 day
% order filled	Decision probabilities	2-way by chance	Fulfilled: 75 %, Partial: 25 %
Fulfilled order	Waiting time to confirm	Normal distribution	Mean: 1 day, Std: 0.3 days
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Delivery product	Transportation time	Constant	1 day

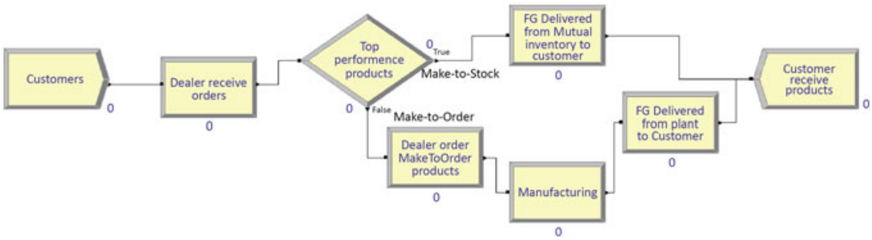

Fig. 69.7 Lean supply chain simulation model

Based on the design of more lean SC, a new simulation model is develop to assess the new total average lead time. Details of the simulation model and assumptions are shown in Table 69.4 and Fig. 69.7 technique application.

After the simulation model rum, the result shows that total average lead time from manufacturer's supply to end user's demand is reduced from 18.85 to 7.2 days.

69.4 Conclusion

This paper presents a case study related to dealer dominant SC where dealers are a very important sale channel for the manufacturer. Dealers have owned key competitive resources to sell products to end users from many manufacturers. They have a big impact on sales volume of each manufacturer and this makes the dealer's bargaining power so powerful. For construction materials industry focused on roof product, the paper indicated the key competitive resources that are very important to companies to maintain their bargaining power in balance. This type of SC setting creates numerous wastes along the SC namely overproduction (because inappropriate rules for order fill) and inventory/space (because of lack of visibility of end users demand). A new scenario, more lean, for the SC is proposed. A simulation study shows that the reduction of wastages along the SC supports the reduction of lead time from manufacturer to end user from 18.85 to 7.2 days.

Acknowledgments The first author would like to thank my advisors Professor Helena Carvalho and Professor V. Cruz-Machado from FCT, Universidade Nova de Lisboa for providing the right mix of Direction and for his/her expertise of supply chain development to help facilitate the completion of this paper. The authors also like to thank to the supply chain managers who gave a very kind collaboration and information sharing under the information restriction of the company. Their time and resources were really appreciated.

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J. Xu et al. (eds.), *Proceedings of the Eighth International Conference on Management Science and Engineering Management*, Advances in Intelligent Systems and Computing 280,
DOI: 10.1007/978-3-642-55182-6,